2017 PURDUE ROAD SCHOOL
MARCH 6-9, 2017

AUTOMATION IN HIGHWAY CONSTRUCTION: SUCCESS, CHALLENGES, AND GUIDANCE

BY
DR. GEORGE K. CHANG
DIRECTOR OF RESEARCH, TRANSTEC GROUP
PRESIDENT, IICTG

IICTG.org

OUTLINES

- Definition of Intelligent Construction Technologies (ICT)
- FHWA ICT Efforts
- Key ICT – Benefits, Challenges and Solutions
- ICT Integration
- ICT Guidance
- Case Studies

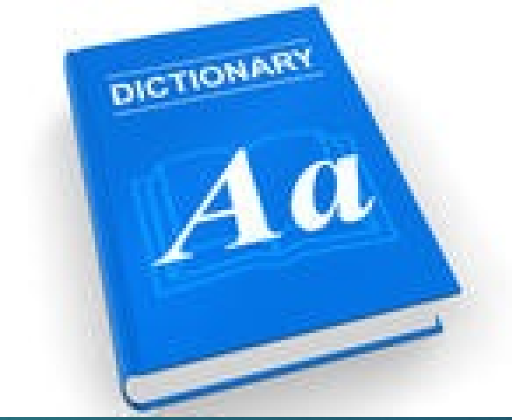
OUTLINES

- **Definition of Intelligent Construction Technologies (ICT)**
- FHWA ICT Efforts
- Key ICT – Benefits, Challenges and Solutions
- ICT Integration
- ICT Guidance
- Case Studies

AUTOMATION IN CONSTRUCTION

INTELLIGENT CONSTRUCTION TECHNOLOGIES (ICT)

DEFINITION OF ICT



Systems and technologies that collect, store, analyze, and process information, make, and execute an action or decision that results in quality construction.

DEFINITION OF ICT

Collect, Store
Analyze, Process
Decision, Execute

Quality Construction

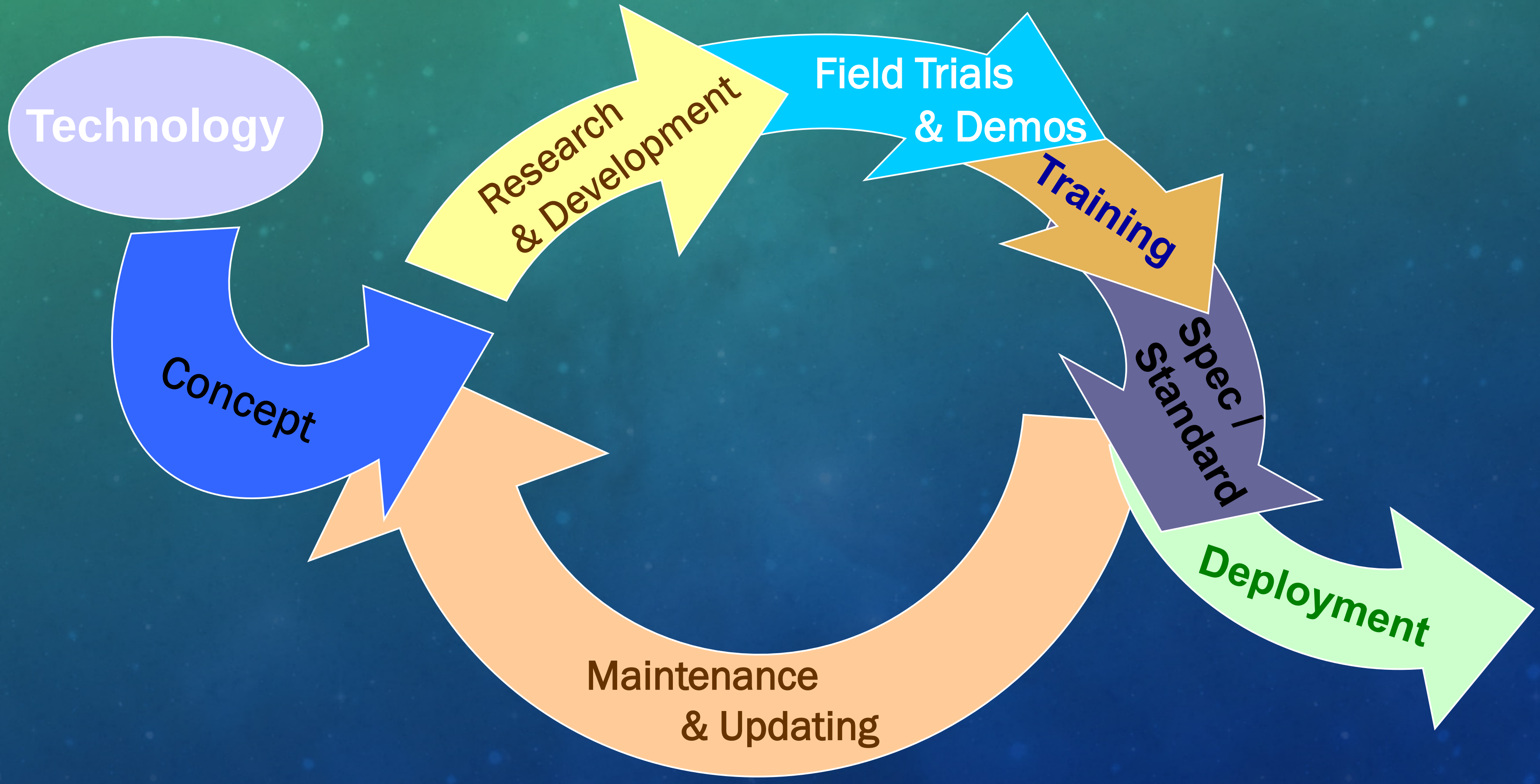
OUTLINES

- Definition of Intelligent Construction Technologies (ICT)
- **FHWA ICT Efforts**
- Key ICT – Benefits, Challenges and Solutions
- ICT Integration
- ICT Guidance
- Case Studies


Computer-Aided Construction Modeling
Surveying
Pavement Materials Production
Machine Guidance
Quality Monitoring
Pay Quantity Measurement and Inspection Records
Data Management
Improved Highway Delivery with the use of Intelligent Construction Systems

ICTG.org

ICT DEVELOPMENT CYCLE



Every Day Counts

FHWA EDC TECH BRIEF

TECHBRIEF

U.S. Department of Transportation
Federal Highway Administration

3D Engineered Models for Construction

UNDERSTANDING THE BENEFITS OF 3D MODELING IN CONSTRUCTION: THE WISCONSIN CASE STUDY

ABSTRACT

To evaluate the benefits of three-dimensional (3D) design data, the Wisconsin Department of Transportation (WisDOT) calculated the return on investment (ROI) for several components of a reconstruction project. The metric showed an improved efficiency in dirt-moving operations and a greater cost savings during construction of other components such as general structures, drainage, and bridges with general use of models for 3D roadway projects.

Lance Parve
Wisconsin DOT
Sr. Project Engineer
lance.parve@dot.wi.gov

Introduction

Transportation agencies have used three-dimensional (3D) modeling in building construction (also known as "Building Information Modeling" [BIM]) effectively for many years. In BIM applications, designers are able to identify early in the process potential construction issues, such as clashes in future piping, wiring, and HVAC ductwork.

In recent years, transportation agencies have started to plan and design roads in 3D because they understand the possible benefits that 3D models offer in construction. The benefits include improved productivity of operations and worker safety. Using 3D models also enhance the bidding process and allow contractors to use Automated Machine Guidance (AMG) to yield higher quality and less expensive construction. Agencies may provide 3D design data to potential bidders, or contractors may develop their own models for use with AMG during construction.

The Wisconsin Department of Transportation (WisDOT) is at the forefront of the movement toward using 3D modeling in roadway construction. While many States recognize the benefits that 3D models provide in earthwork operations in road construction, WisDOT's Return on Investment (ROI) calculation, using actual project data, shows that 3D modeling can result in even more significant gains during construction of roadway structures and features. WisDOT is currently verifying early ROI projections on the Zoo Interchange Project, a freeway interchange on the west side of Milwaukee.

TECHBRIEF

U.S. Department of Transportation
Federal Highway Administration

3D Engineered Models for Construction

CASE STUDY FOR POLICIES AND ORGANIZATIONAL CHANGES FOR IMPLEMENTATION: THE KENTUCKY CASE STUDY

ABSTRACT

This case study provides an example of how the Kentucky Transportation Cabinet was able to innovate and make better use of three-dimensional design data for construction applications. This seamless transition from design to bid to build has improved highway delivery for the State of Kentucky.

Christopher Schneider, FHWA-HQ
christopher.schneider@dot.gov
202.493.0551

Jason Littleton, PE, LSIT
jason.littleton@ky.gov
502.564.3280 (x3430)

Introduction

The building construction industry began using three dimensional (3D) engineered models in the 1980s because of the greater efficiency, reduced schedule, and reduced cost offered by this approach. Today, 3D modeling for building construction has become the standard for design and construction of commercial and industrial buildings. Known as Building Information Modeling (BIM), the concept goes beyond planning and design phases of the project and extends throughout the building life-cycle to support cost management, construction management, project management, and even facility operation. While lagging behind BIM, the use of 3D models for horizontal construction, also known as Civil Integrated Management, represents roadway construction in digital form and has been shown to accelerate construction operations, improve accuracy, reduce cost, and increase safety on jobsites.[1]

Highway construction contractors began using 3D modeling for transportation projects in the 1990s. Typically contractors would "reverse engineer" 2D plans developed by State agencies to use for automated machine guidance. Many State transportation agencies have developed the capability and resources to develop 3D models, with potential for use as legal and binding documentation. However, State specifications typically are not written to accommodate the nuances associated with the full application of 3D modeling for roadway construction.

1 Washington DC, Federal Highway Administration: 3D Engineered Models for Construction – Implementation Plan, March 2013.

TECHBRIEF

U.S. Department of Transportation
Federal Highway Administration

3D, 4D, and 5D ENGINEERED MODELS FOR CONSTRUCTION

EXECUTIVE SUMMARY | MARCH 2013

ABSTRACT

This Technical Brief provides an overview of 3D modeling, including technology applications during design and construction, benefits to stakeholders, resource requirements, current state-of-the practice, and advanced applications such as adding 4D and 5D components.

- Improved project delivery
- Improved communication
- Enhanced identification of errors
- Improved visualization

Christopher Schneider, FHWA-HQ
Christopher.Schneider@dot.gov
202.493.0551

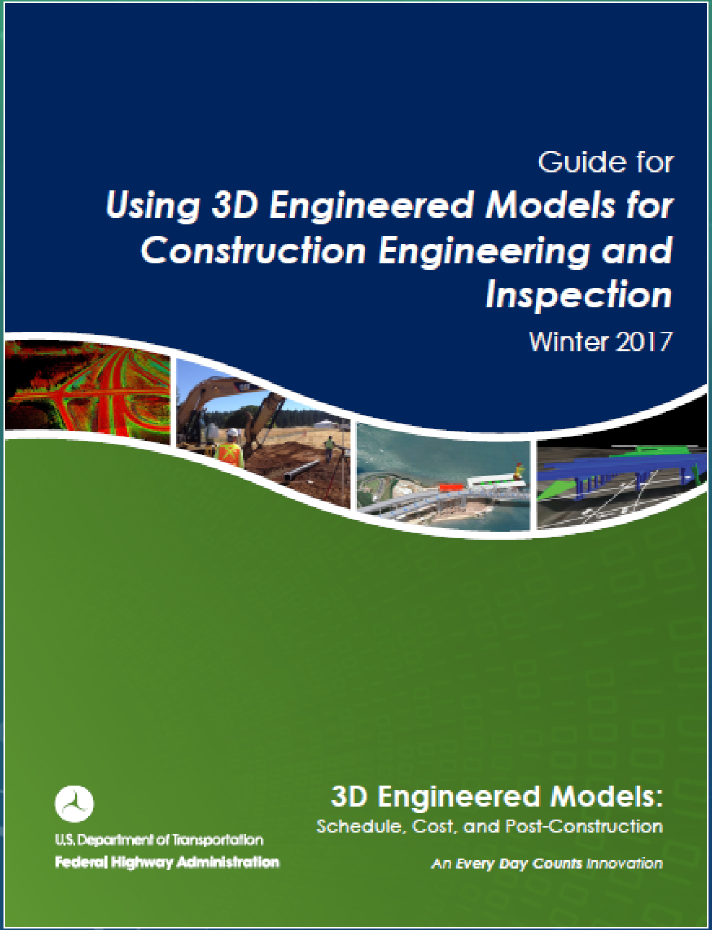
INTRODUCTION

Three-dimensional engineered models (3D models) for construction provide transportation agencies, contractors, and consultants a better understanding of the design with a virtual representation of project design. 3D models allow for identification of potential conflicts and/or errors in design compared to traditional design and construction techniques using 2D plans and profiles. 3D models illustrate a project in a digital form that can then be analyzed to determine inconsistencies that would normally not be discovered until the construction phase. The model can be tilted, rotated, and manipulated to provide various views of the designed roadway prism and features. While there are design benefits to using 3D models with visualization capabilities, perhaps a more significant benefit is that the data can be processed and used to automate construction activities.

For the last two decades, the vertical construction industry has used 3D models to improve the process for constructing buildings and other structures. This same process has been applied in several states to the horizontal (highway) construction industry. But more work can be done to advance the state-of-the-practice in use of 3D models. Agencies might begin with pilot projects or perform a full transition from 2D to 3D design shops. Often, contractors lead implementation by developing 3D models post bid.

4D modeling allows stakeholders to visualize construction over the project duration to identify potential spatial/temporal conflicts in schedule. Adding a cost component to the process creates a 5th dimension, making a 5D model. Such 5D engineered models allow stakeholders to evaluate costs and model cash flows for each phase of construction.

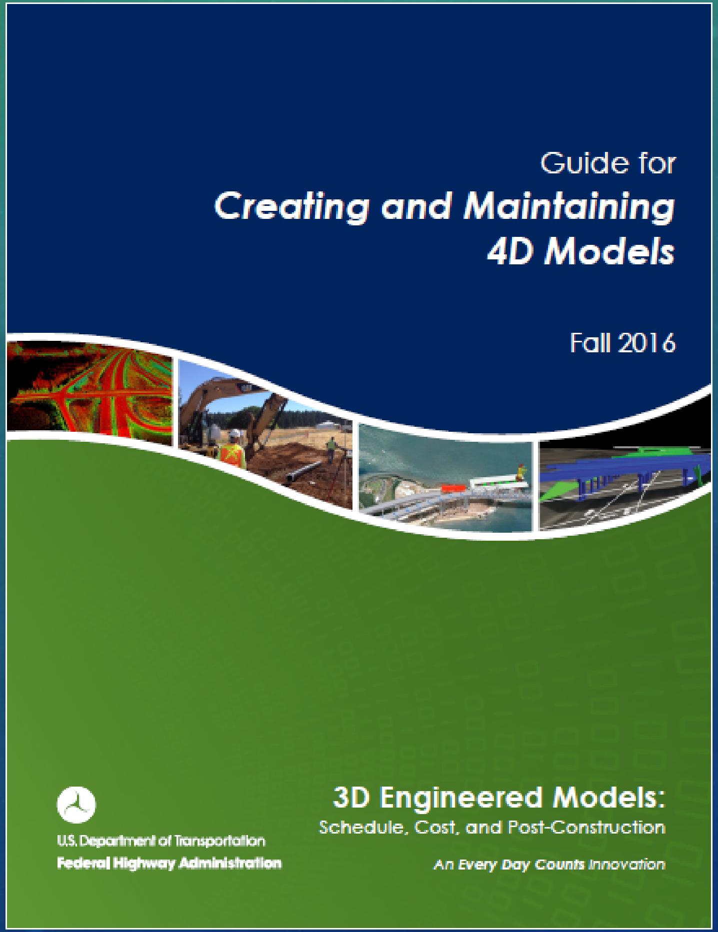
FHWA GUIDE DOCUMENTS



Guide for
Using 3D Engineered Models for Construction Engineering and Inspection
Winter 2017

U.S. Department of Transportation
Federal Highway Administration

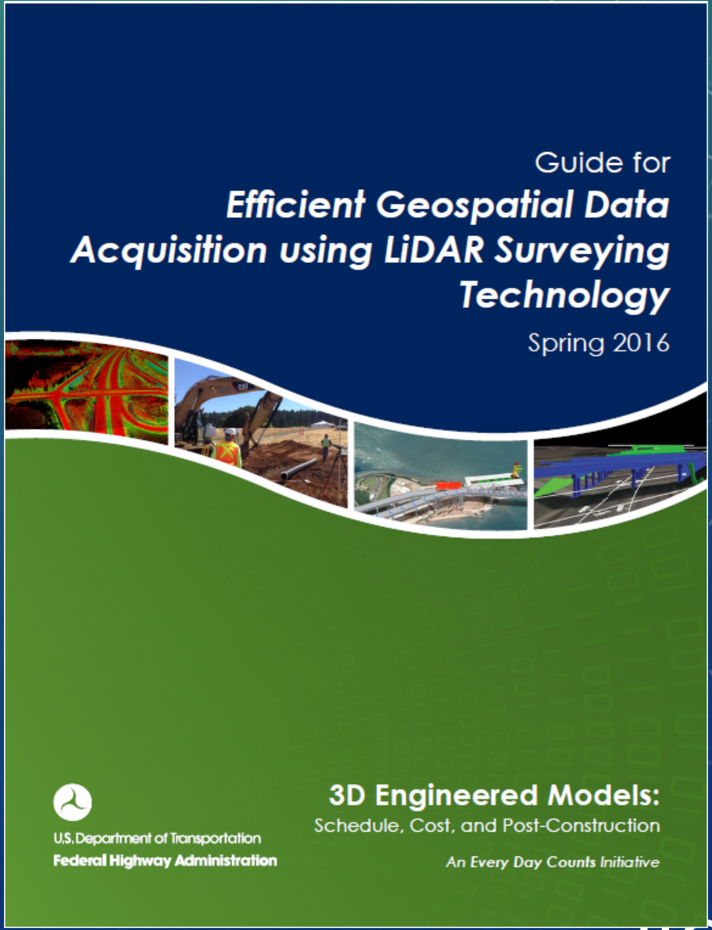
3D Engineered Models:
Schedule, Cost, and Post-Construction
An Every Day Counts Innovation



Guide for
Creating and Maintaining 4D Models
Fall 2016

U.S. Department of Transportation
Federal Highway Administration

3D Engineered Models:
Schedule, Cost, and Post-Construction
An Every Day Counts Innovation



Guide for
Efficient Geospatial Data Acquisition using LiDAR Surveying Technology
Spring 2016

U.S. Department of Transportation
Federal Highway Administration

3D Engineered Models:
Schedule, Cost, and Post-Construction
An Every Day Counts Initiative

FHWA EDC 3D WORKSHOPS

Table of Contents

FHWA 3D EDC WORKSHOPS

Planning Element	Level of Maturity						Maturity Goals		
Strategy	0 None	1 Initial	2 Evolving	3 Defined	4 Managed	5 Enhanced	Baseline	Short-term	Ultimate
Organizational Vision and Goals	No 3D Modeling vision or goals defined	Broad vision for adopting 3D Modeling	Vision for adopting 3D Modeling for some project types	Vision for 3D Modeling for some project types across all project phases	Vision for 3D Modeling for all project types across all project phases	Vision for 3D Modeling for all projects	2	3	3
Management Support	No Management support	Limited support for feasibility study	Management have reviewed feasibility study and support further exploration	Funding for creating an implementation plan	Funding for pilot initiatives and/or enabling infrastructure	Implementation Plan is fully funded over the duration of execution	2	4	5
Champions	No Champions identified	Champions identified but no formal accountability	Champions have role incorporated into job function	Champions within each department or working group	Executive-level Champion with limited time commitment	Executive-level Champion works closely with others	0	3	4
Implementation Plan	No Planning Committee established	Planning Committee established	First draft Implementation Plan	Implementation Plan adopted and underway	Implementation Plan has been through one review cycle	Implementation Plan has been through multiple review cycles	0	2	3
Enabling Infrastructure	0 None	1 Initial	2 Evolving	3 Defined	4 Managed	5 Enhanced	Baseline	Short-term	Ultimate
Statewide Continuously Operating Reference Station (CORS) Network	None	Limited access to a CORS network	Statewide CORS network that is	Limited access to survey-grade	Statewide CORS network that is	Publically-owned statewide survey- … CORS network	1	3	4
Real Time GNSS Network (RTN)	None					… CORS RTN solution tied with statewide access	3	4	5
Computer Hardware for Design	None					… ve access to Desktop … obile computers	3	4	5
Computer Software for Design	None	Email, Internet, PDF and Office software only	CADD design software for designers and technicians	CADD design software for all and limited access to design review software	All design staff have CADD design and design review software	Desktop and Mobile CADD design and design review software for all staff	4	4	5
3D Model specification	Printed deliverables only					… ecification required on all projects	1	3	4
Secure, managed file sharing environment	None					… anaged file sharing … ent for all projects.	2	3	4
Electronic Signing & Sealing	Release only paper documents	… only	… on PDF documents	… documents	… documents	… les are electronic with digital sign & seal	2	2	4
Construction Specifications	Method Specification may inhibit the use of new technology	Special Provisions developed to …	Draft AMG specification developed	AMG specification incorporated in …	Draft Specification developed that …	Quality Assurance Specification … of evolving technology	2	4	5
Computer Hardware for Construction	None					… computers and mobile … all construction sites	3	4	5
Computer Software for Construction	None					… d Mobile Construction … are is available	1	3	5
RTK GNSS Receivers (Rovers)	None	Specification allows using the contractor's Rovers	Specification requires contractor to furnish Rovers and training	Limited agency-owned Rovers	Agency-owned Rovers available to all Construction sites	All Construction staff have Rovers and are trained to use them.	3	4	4

Adapted from BIM Planning Guide for Facility Owners v2.0 (Penn State, June 2013) by Francesca Maier, PE and the Technical Working Group

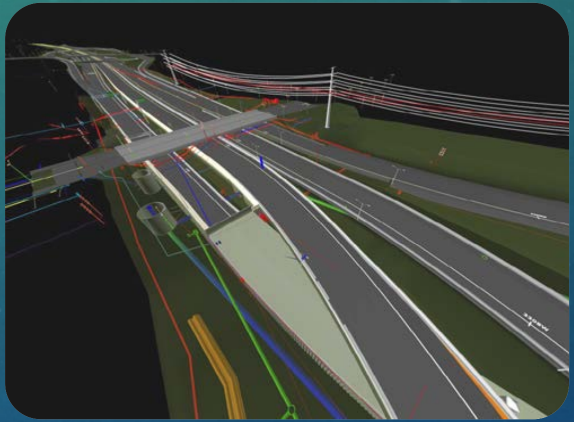
Self-Assessment Tool

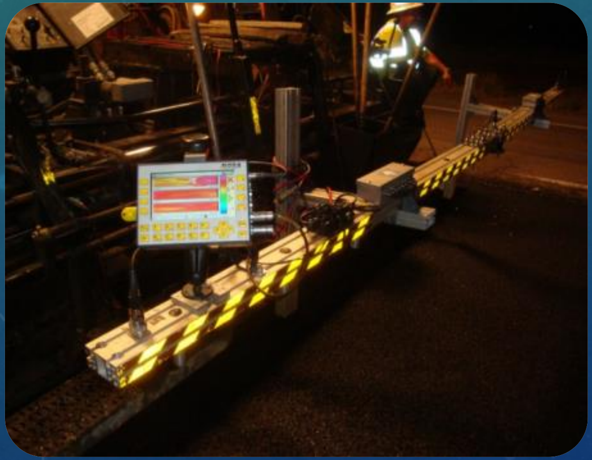
Project Phase Inputs

Applications Matrix

IICTG.org

FHWA
AUTOMATION IN HIGHWAY CONSTRUCTION - ICT





FHWA AUTOMATION IN HIGHWAY CONSTRUCTION RESEARCH TEAM

Dr. George Chang

Francesca Maier

Mauricio Ruiz

Dr. Jag Mallela

Helga Torres

The Transtec Group

Parsons Brinckerhoff

IICTG.org

AUTOMATION IN HIGHWAY CONSTRUCTION FINAL REPORT

DTFH61-13-C-00026

ADDRESSING CHALLENGES IN AUTOMATION IN HIGHWAY CONSTRUCTION

Draft Final Report

Part I: Implementation Challenges at State Transportation Departments and Success Stories

Submitted to:
Federal Highway Administration

Submitted by:
The Transtec Group, Inc.

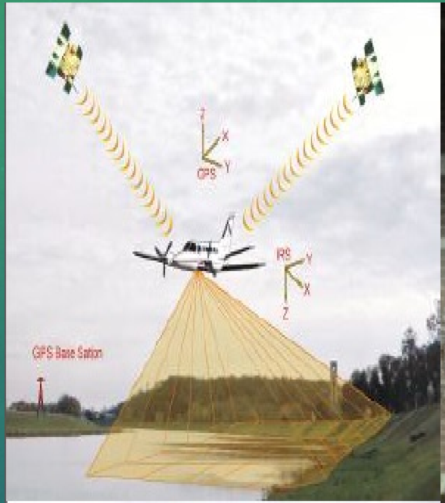
OUTLINES

- Definition of Intelligent Construction Technologies (ICT)
- FHWA ICT Efforts
- **Key ICT – Benefits, Challenges and Solutions**
- ICT Integration
- ICT Guidance
- Case Studies

KEY ICT TECHNOLOGIES

- Integrated Surveys
- Underground Utilities Location
- 3D Designs and Modeling
- Automation in Construction
- Real Time Monitoring and Inspection
- Civil Integrated Management

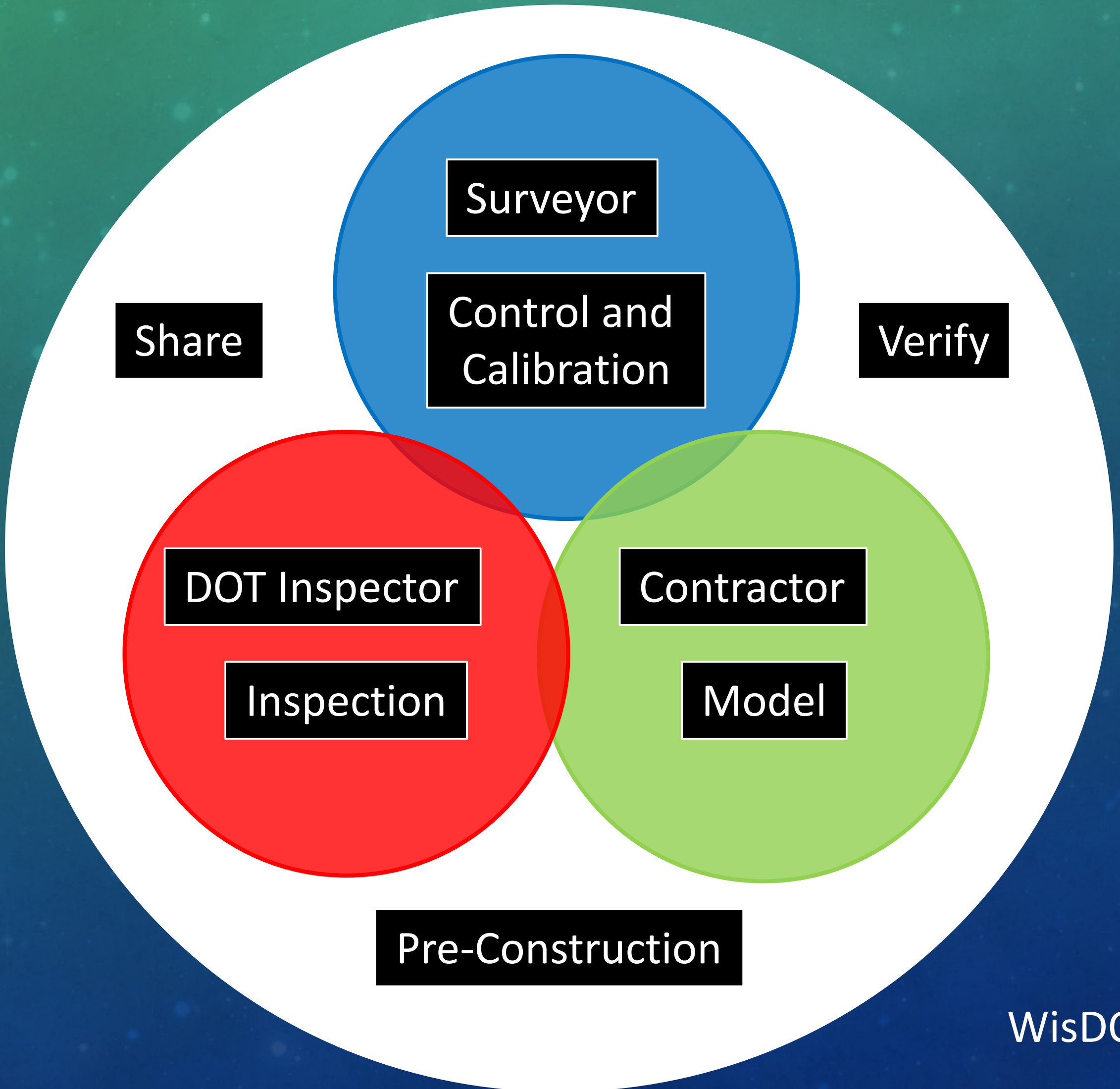
INTEGRATED SURVEYS



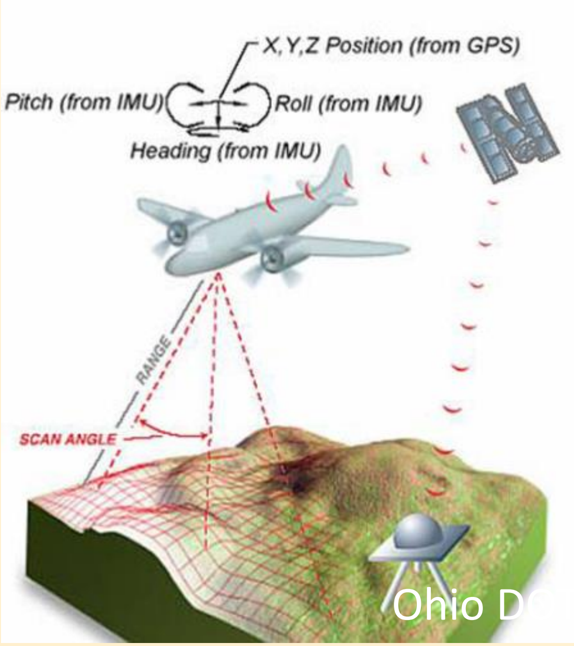


WisDOT ICTG.org

SURVEY DATA AND INTERACTION



AIRBORNE , MOBILE & STATIC TERRENTIAL LIDAR



SURVEY PRECISION

- GPS is highly reliable horizontally
- GPS alone limited the vertical control required for the project
- Preconstruction CM team control checks / densification / vertical improvements
- Digital levels run through all primary control to allow tighter calibrations
- Verified control published to all contractors

VERTICAL PRECISION

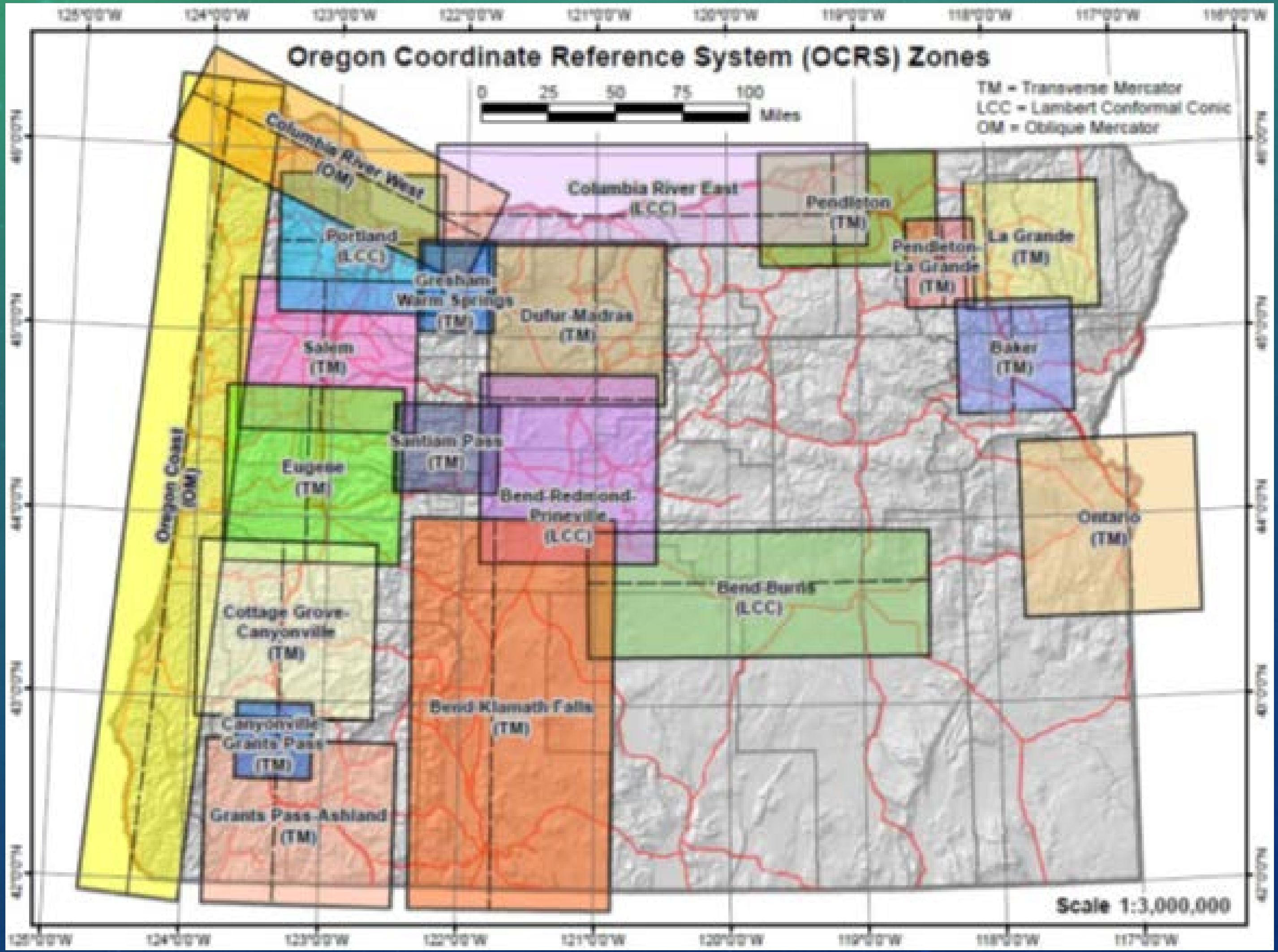
- Fixed Wing Aerial Photogrammetry: ±6” (15cm)
- Low Altitude Helicopter Photogrammetry: ±1”~2” (2.5 ~ 5.0cm)
- Mobile LiDAR Laser Scanning: ±½”~1” (1.3 ~ 2.5cm)
- RTK GPS: ±½” ~1” (1.3 ~ 2.5cm)
- Static LiDAR: ±¼” ~½” (6.4 ~ 13 mm)
- Total Station: ±¼” ~½” (6.4 ~ 13 mm)

LIDAR PRECISIONS

FHWA Geospatial Guide

Method	Network Accuracy (RMS)	
Fixed Wing Aerial LiDAR/Photogrammetry	3" - 6"	
Low Altitude Helicopter LiDAR/Photogrammetry	1" - 2"	
Mobile LiDAR	½" - 1"	
Tripod-Mounted Static LiDAR	¼" - ½"	

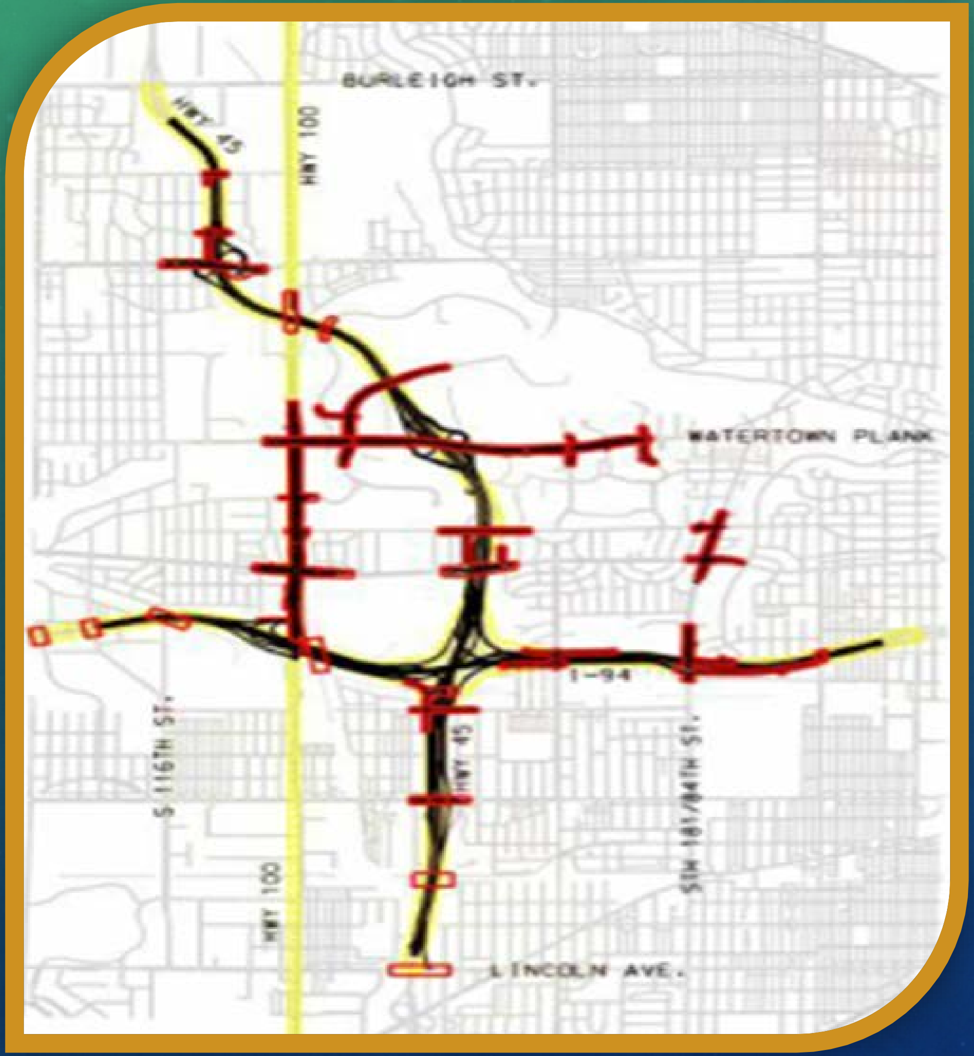
HIGH PRECISION & LOW DISTORTION - CORS

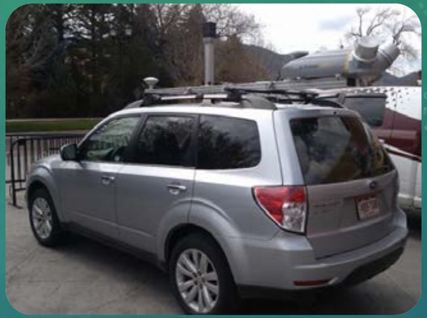


ORDOT

IICTG.org

INTEGRATED SURVEY APPROACH





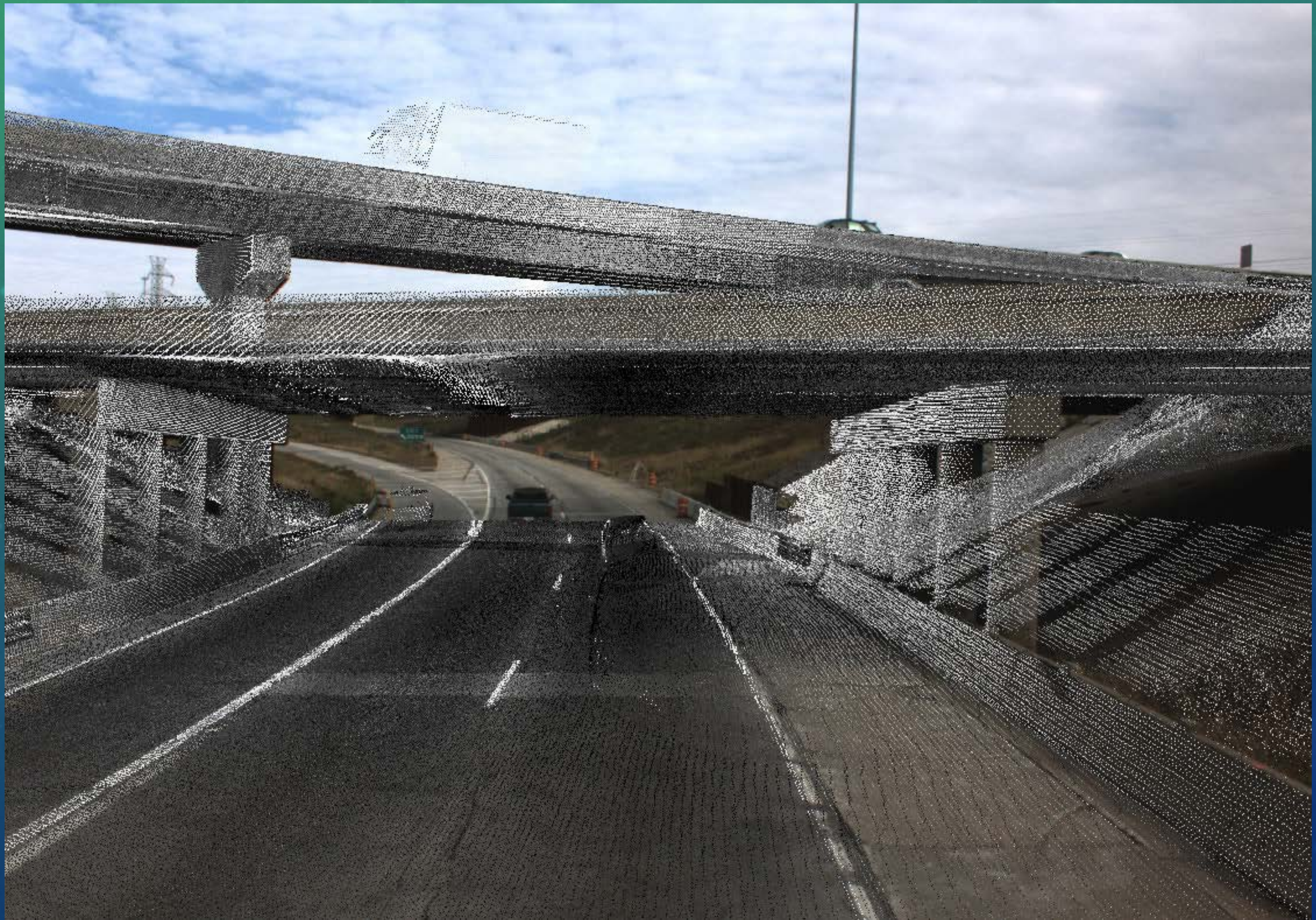
Mobile LiDAR scan area

Stationary scan area

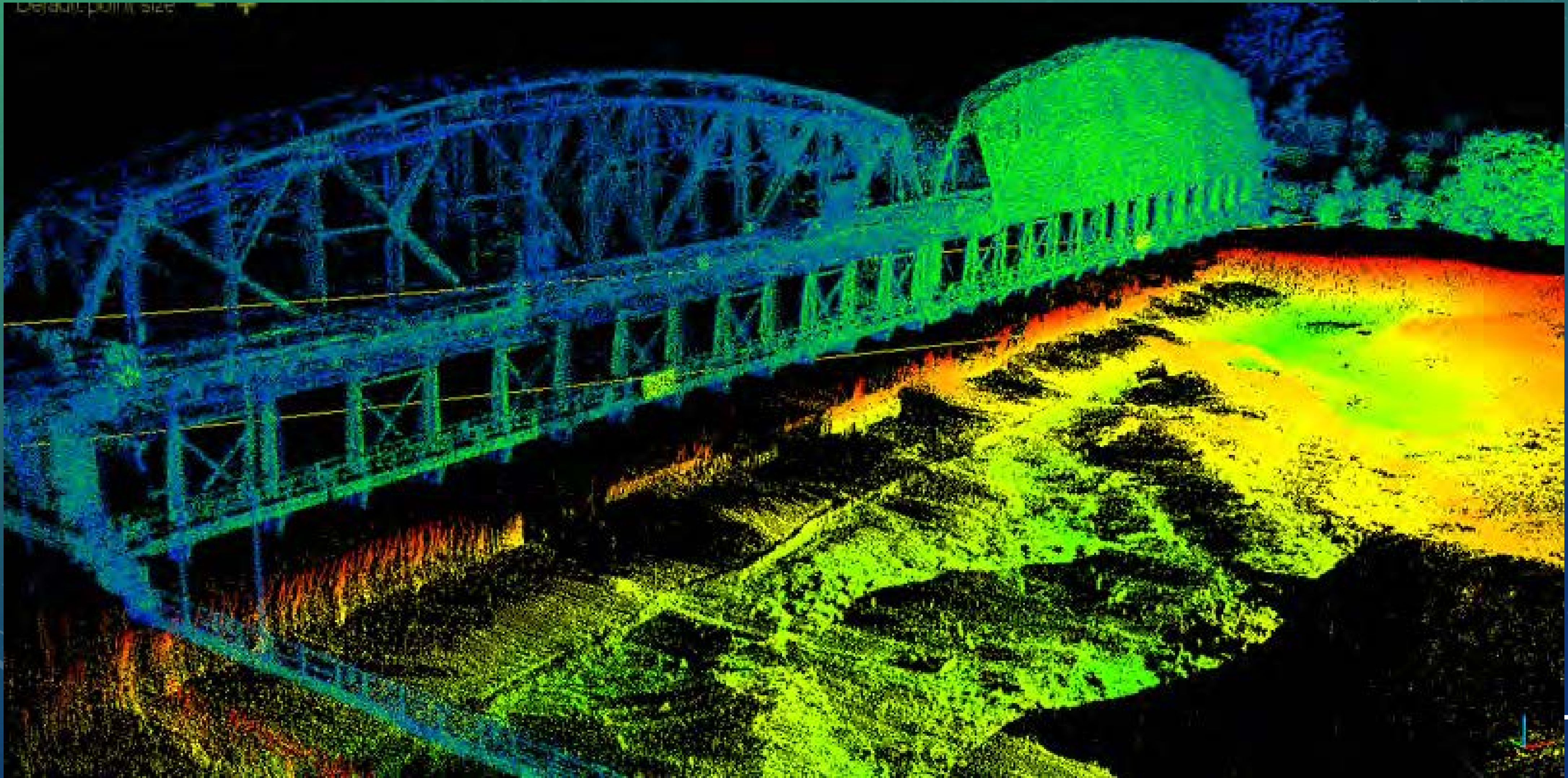
Proposed Design

WisDOT

LIDAR POINT CLOUD



LIDAR POINT CLOUD



TG.org

OPTIMIZE QUANTITY

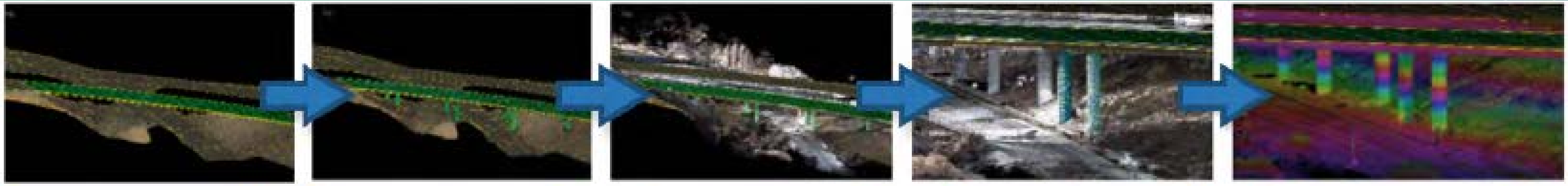
Data Source:
3D Cloud Point
Aerial Imagery

Process:
Add Breaklines and Mass Points
Extract Topographic Features

Final Product:
QL2 Bare Earth Point Cloud
DTM (Breaklines/Mass Points)
CADD Topographic Drawing

NCDOT

DATA FUSION TO CREATE DTM



Derived Product:
DTM

File Types: Caice, DWG

Processing Software:
Trimble, Leica Cyclone, Caice, Civil 3D

Derived Product:
DTM
3D Structure Mesh

File Types: Caice, DWG, DGN

Processing Software:
Trimble, Leica Cyclone, Caice, Civil 3D, MicroStation

Derived Product:
DTM
3D Structure Mesh
3D Point Cloud

File Types: Caice, DWG, DGN, LAS

Processing Software:
Trimble, Leica Cyclone, Caice, Civil 3D, MicroStation, ArcGIS

Reality Capture:
DTM
3D Point Cloud with RGB Values
Survey 3D Features

File Types: Caice, DWG, DGN, LAS

Processing Software:
Trimble, Leica Cyclone, Trident 7.1, Applanix PosPac MMS 7.1, TopoDOT, Caice, Civil 3D, MicroStation, ArcGIS

Added Value Product:
3D Survey Grade DTM
3D Elevation and Intensity Values

File Types: CADD, and GIS

KEY BENEFITS

Survey data collection **time** and **cost** savings

Improved **safety**

Example:

Utah DOT - Asset Management Mapping Grade LiDAR for Design (Searle et al. 2014)

24% cost savings, 22% time savings, increased safety

KEY BENEFITS

Increased level of **detail**, **accuracy**, and **scalability**

Example:

Alabama DOT: Evaluating Mobile Scanning Data for use within a State DOT (Russell 2012)

improved quantity estimates

rutting and pavement condition, guard rails, bridges, overhead utilities, signs, etc.

CHALLENGES

- Cost is the most significant challenge
- More evidence and education needed regarding the benefit-to-cost comparison

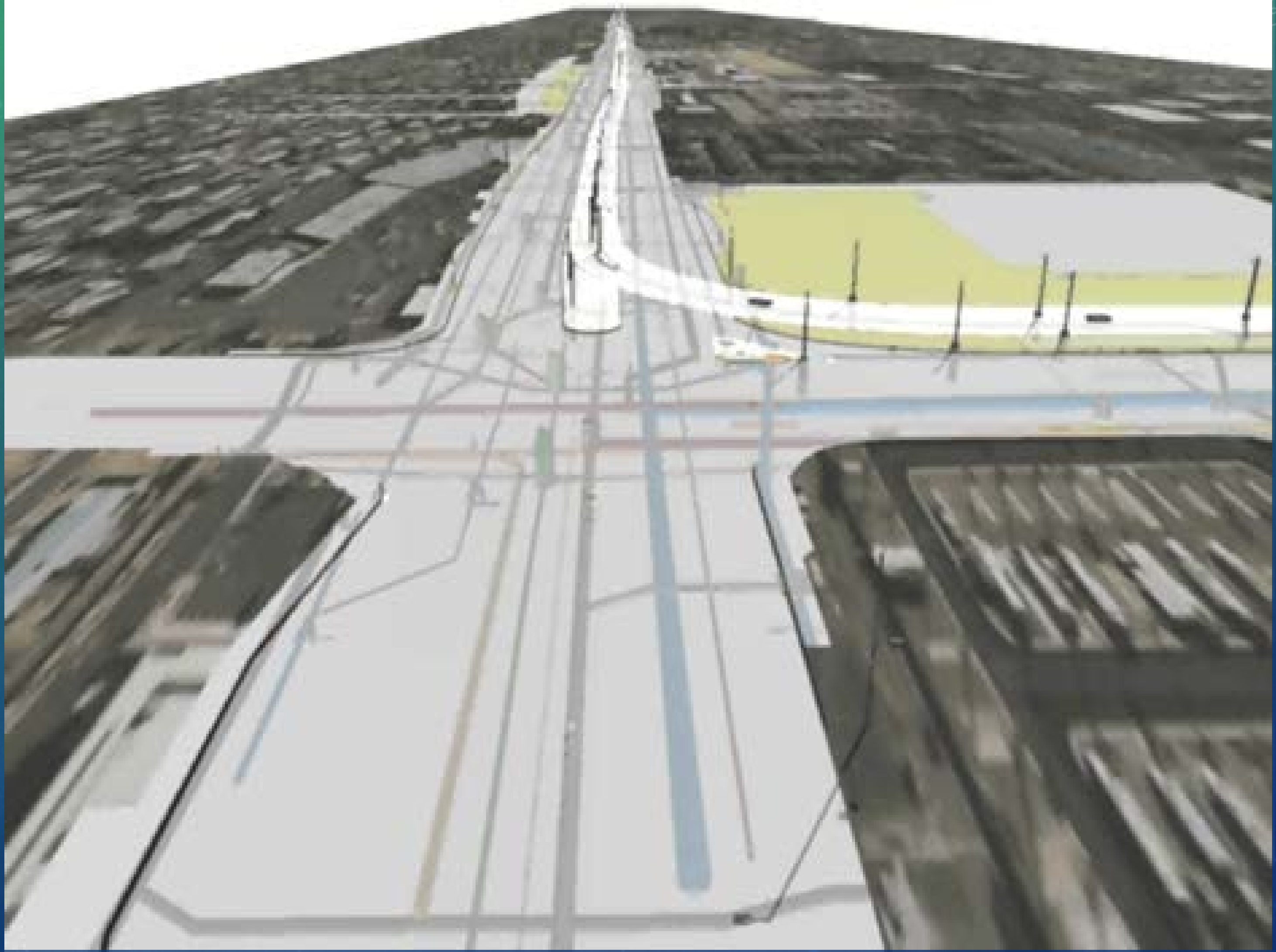
2013 Survey on mobile LiDAR at State DOTs (Hurwitz et al.)

Challenges	Solutions
Cost (Equipment and data collection)	Acquire and share info between agencies; i.e., Oregon LiDAR consortium

CHALLENGES

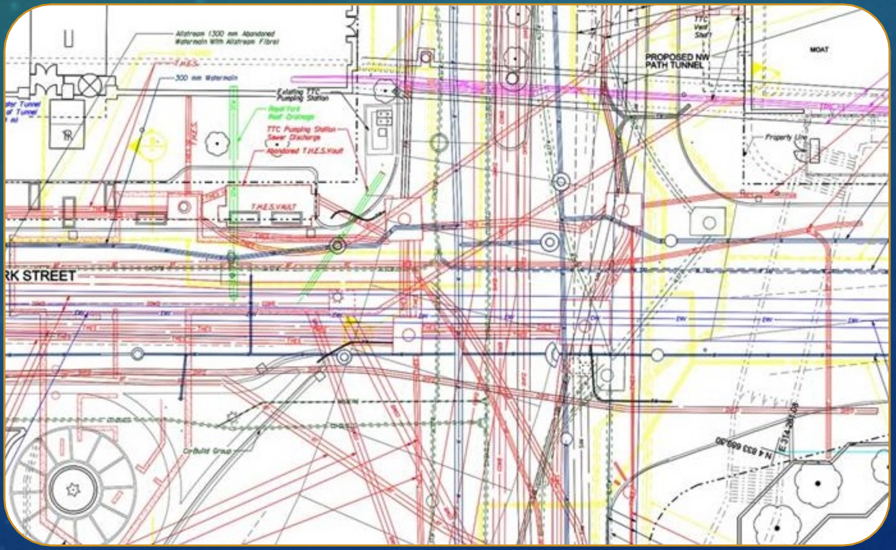
Challenges	Solutions
Lack of Standards, Interoperability	• American Society of Photogrammetry and Remote Sensing (ASPRS): LAS format • The ASTM E57 committee: format E57 for 3D imaging systems
Data Management	• Positions to facilitate data flow between design and construction • Dedicated IT staff in design sections to support 3D design efforts

UNDERGROUND UTILITIES LOCATION

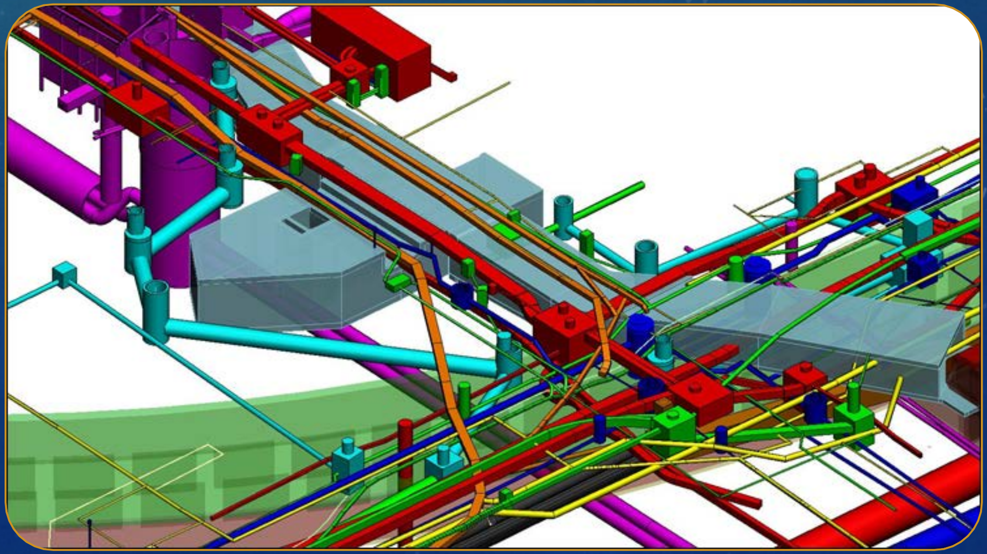


UNDERGROUND UTILITIES LOCATION

- 3D modeling software + underground location technologies
- 2015 FHWA Report: *Feasibility of Mapping and Marking Utilities*



(Hatch Mott MacDonald)



KEY BENEFITS

More accurate information regarding existing utilities is needed, especially in urban environments,

- identify conflicts during design
- avoid guess work and digging during construction which results in significant cost, delays, change orders, claims, and damages.

CHALLENGES

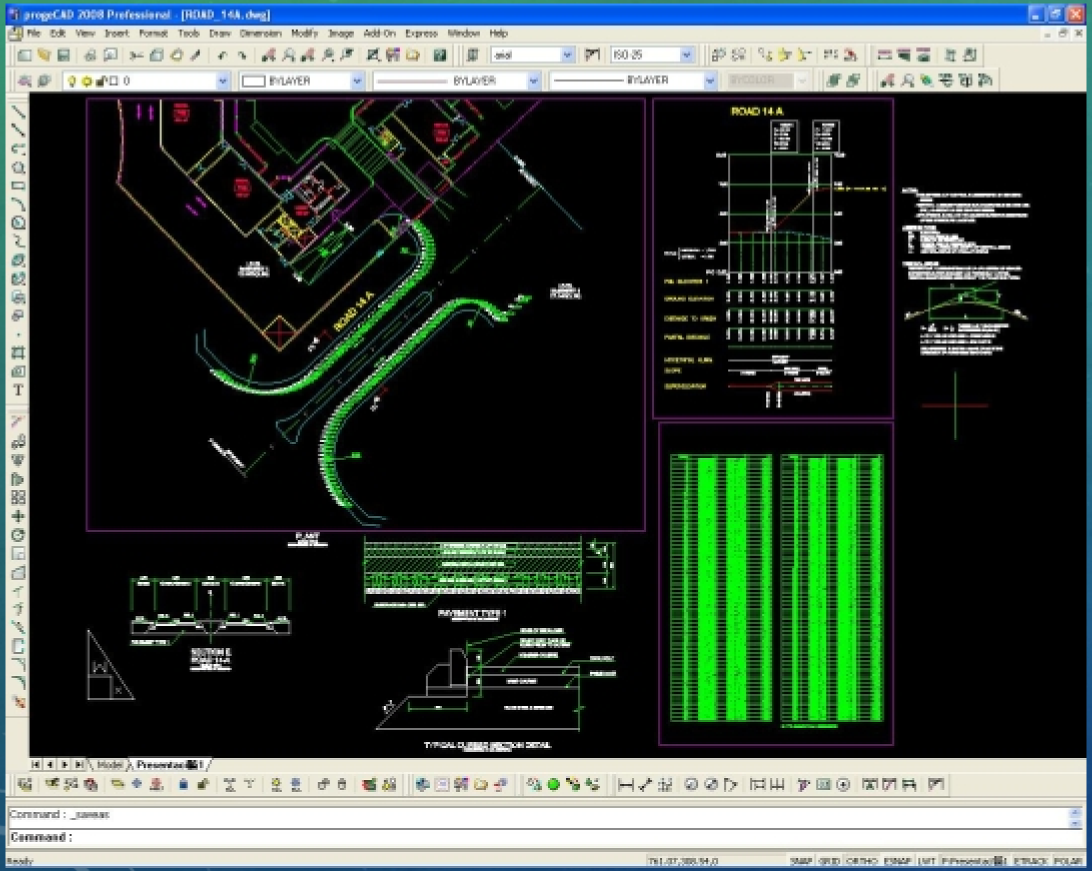
- Agencies/designers work with inaccurate, low quality information from utility companies
- Liability for utility conflicts and relocation is placed on the contractor

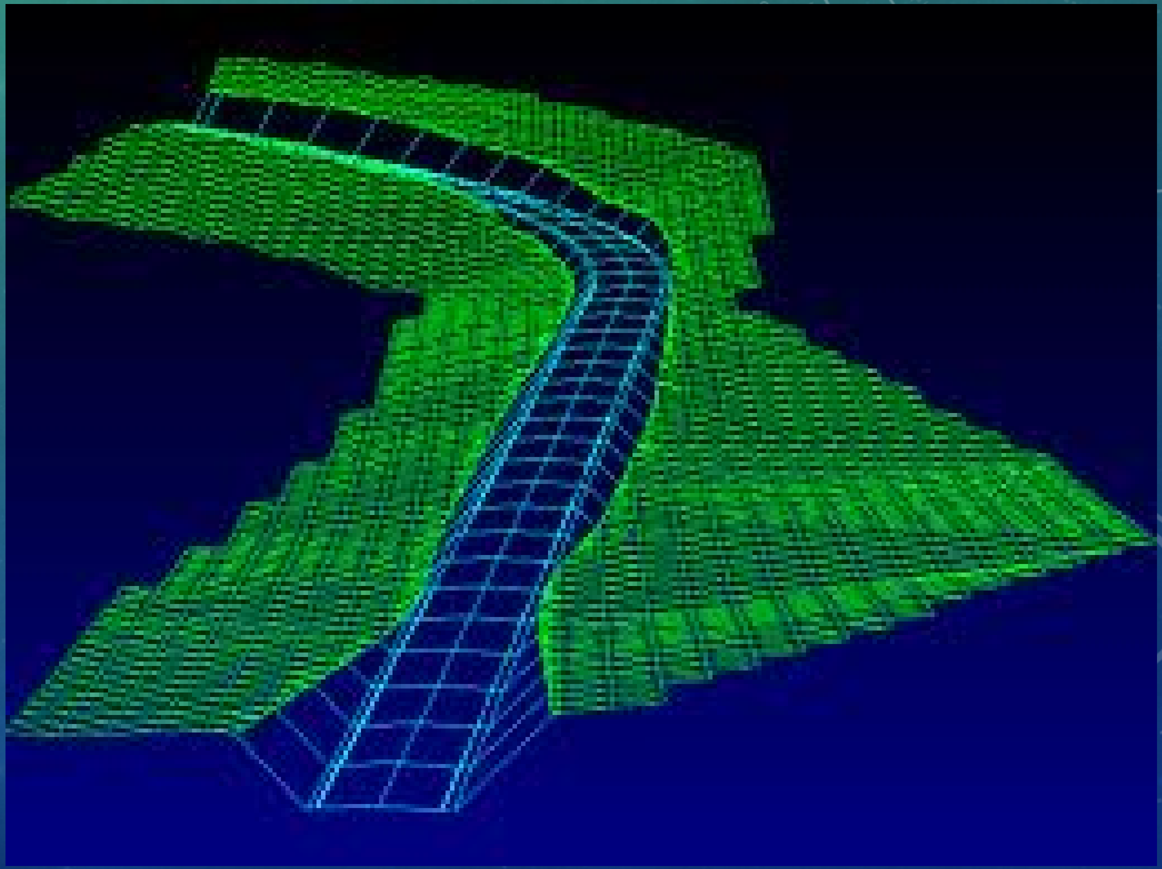
CHALLENGES

Challenges
Unknown or mistakenly recorded utilities (*R01A Technologies to Support Storage, Retrieval, and Utilization of 3-D Utility Location Data*)
Locating underground utilities across a variety of soil conditions (*R01B Utility Locating Technology Development Utilizing Multi-Sensor Platforms*)
Locating deep underground utilities (*R01C Innovation in Location of Deep Utility Pipes and Tunnels)*

FHWA, SHRP2

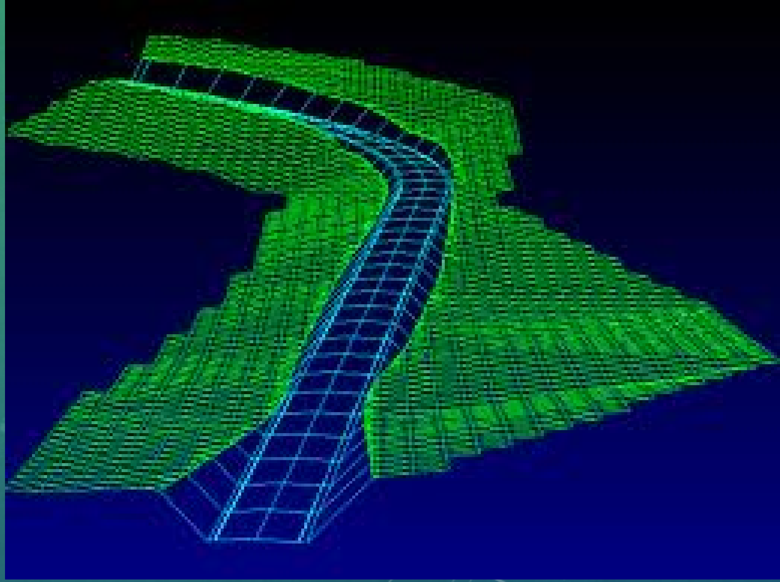
3D DESIGN AND MODELS





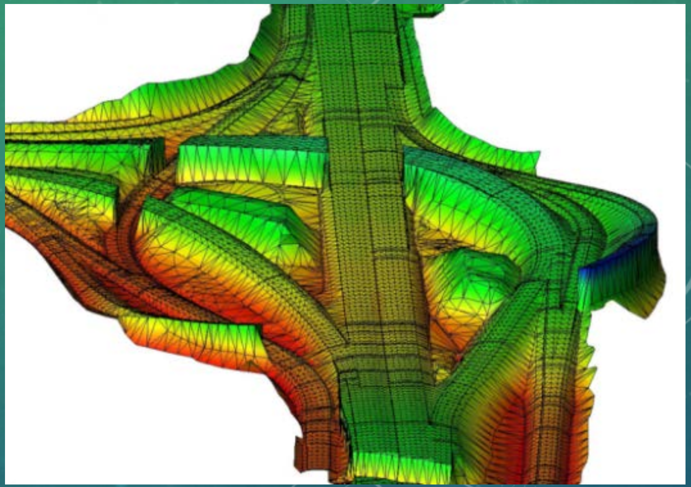
IICTG.org

3D COMPUTER-AIDED DESIGN MODEL



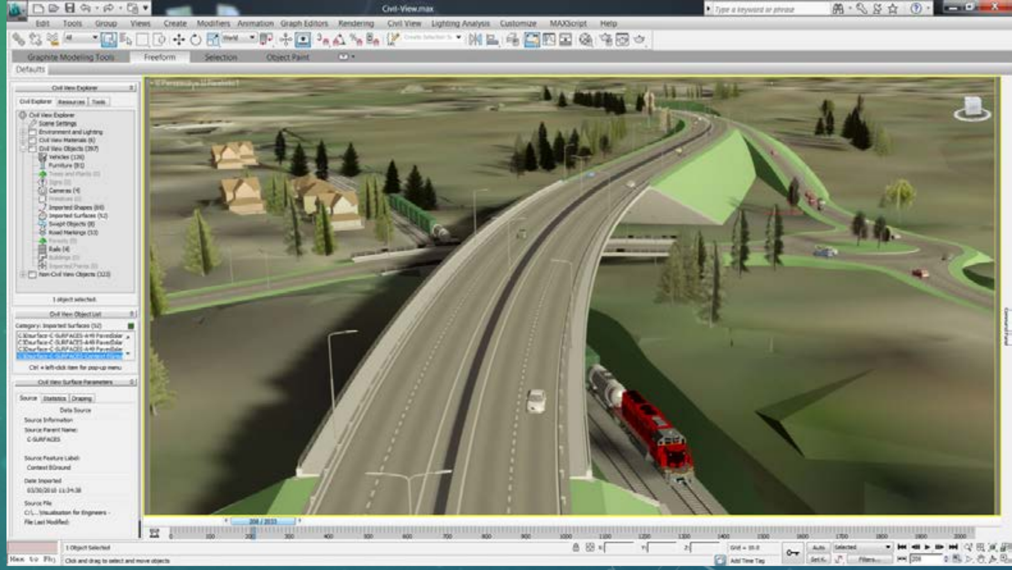
- Real-time field verification with GPS rovers,
- Surface-to-surface accurate volume, and
- Export design information shared by designers, surveyors, and inspectors.
- 3D design is a key process for implementing ICST.

3D MODELING



(CES, LLC)

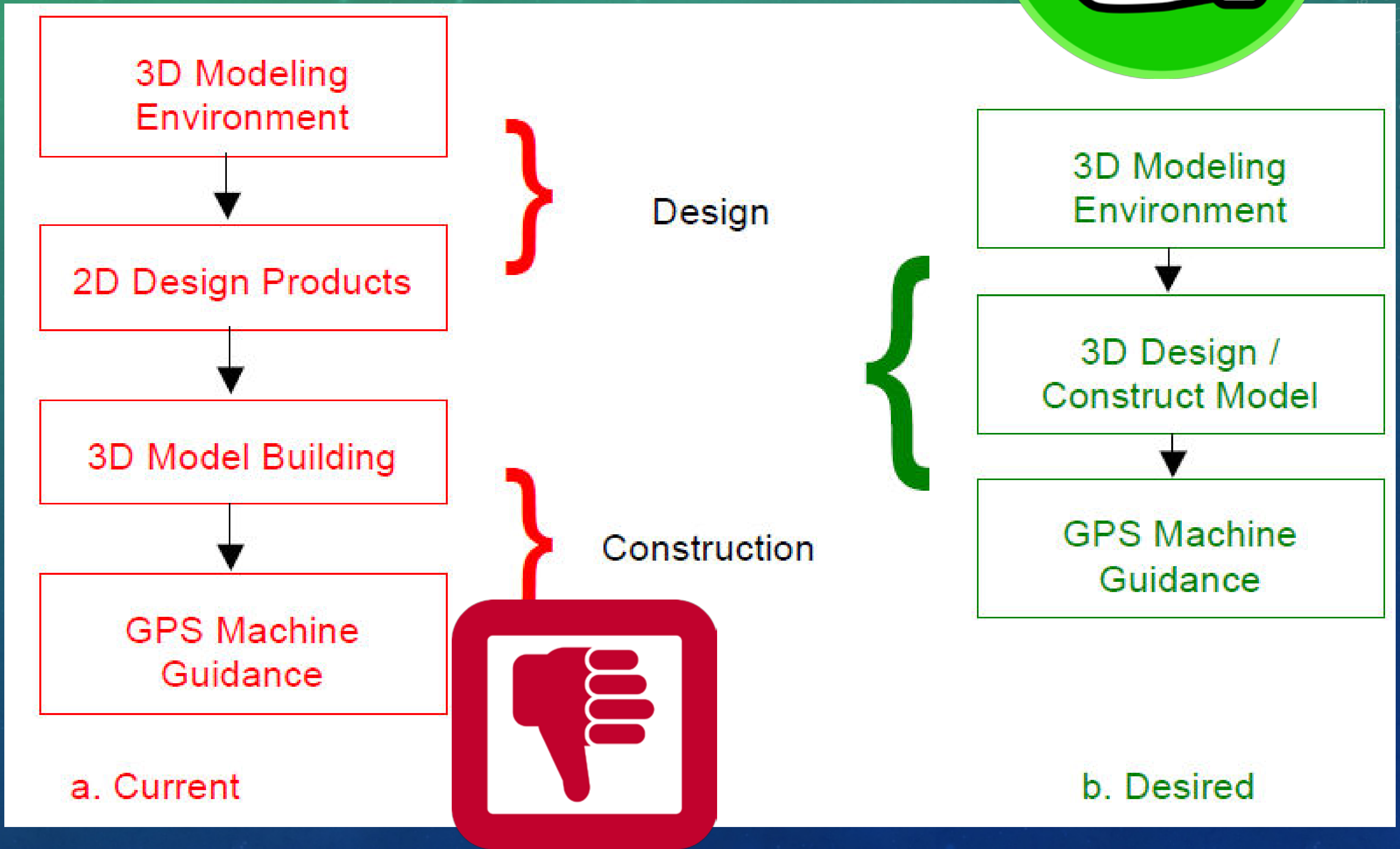
- **3D design is a key process for implementing automation in construction**
  - Transition from 2D to 3D design at DOTs has been driven by contractors using Automated Machine Guidance
- Once transition to 3D design is underway, DOTs benefit of 3D modeling throughout all phases of a highway project



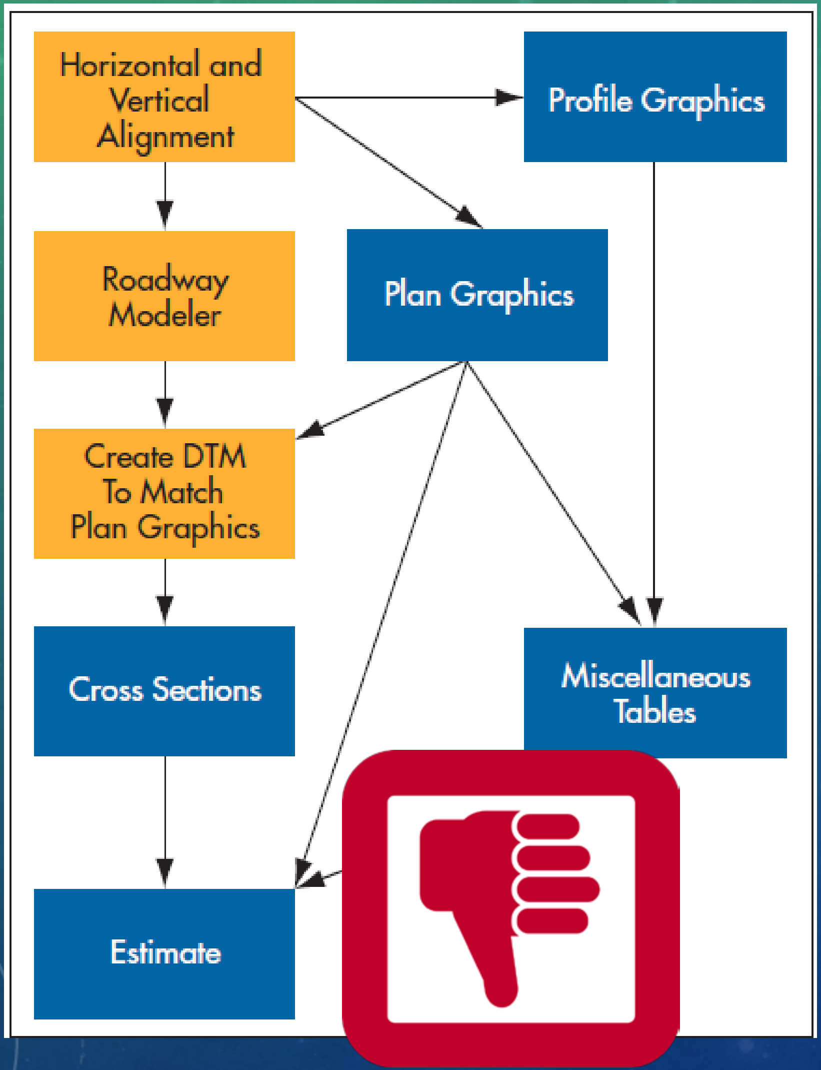
3D SOFTWARE TOOLS

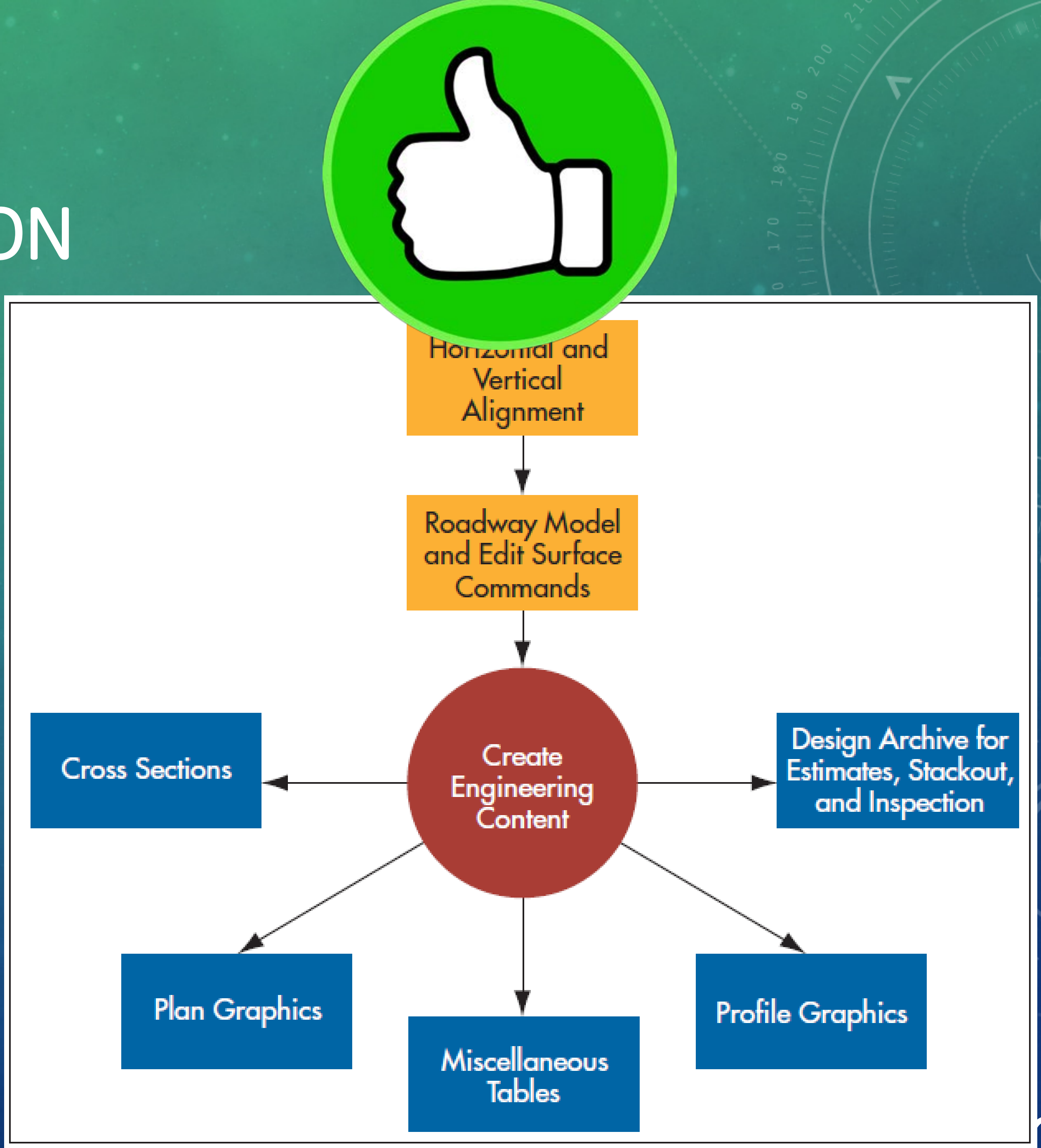
- Civil 3D
  - CM team wanted to use C3D to work within the new approved software platform and help develop the DOT process. Started with the idea of having an independent model to check against contractor model.
  - Software wasn’t ready for a model of this scale.
- Terramodel
  - Changed to Terramodel to integrate and collaborate more efficiently with the contractors model

3D DESIGN AND MODELING



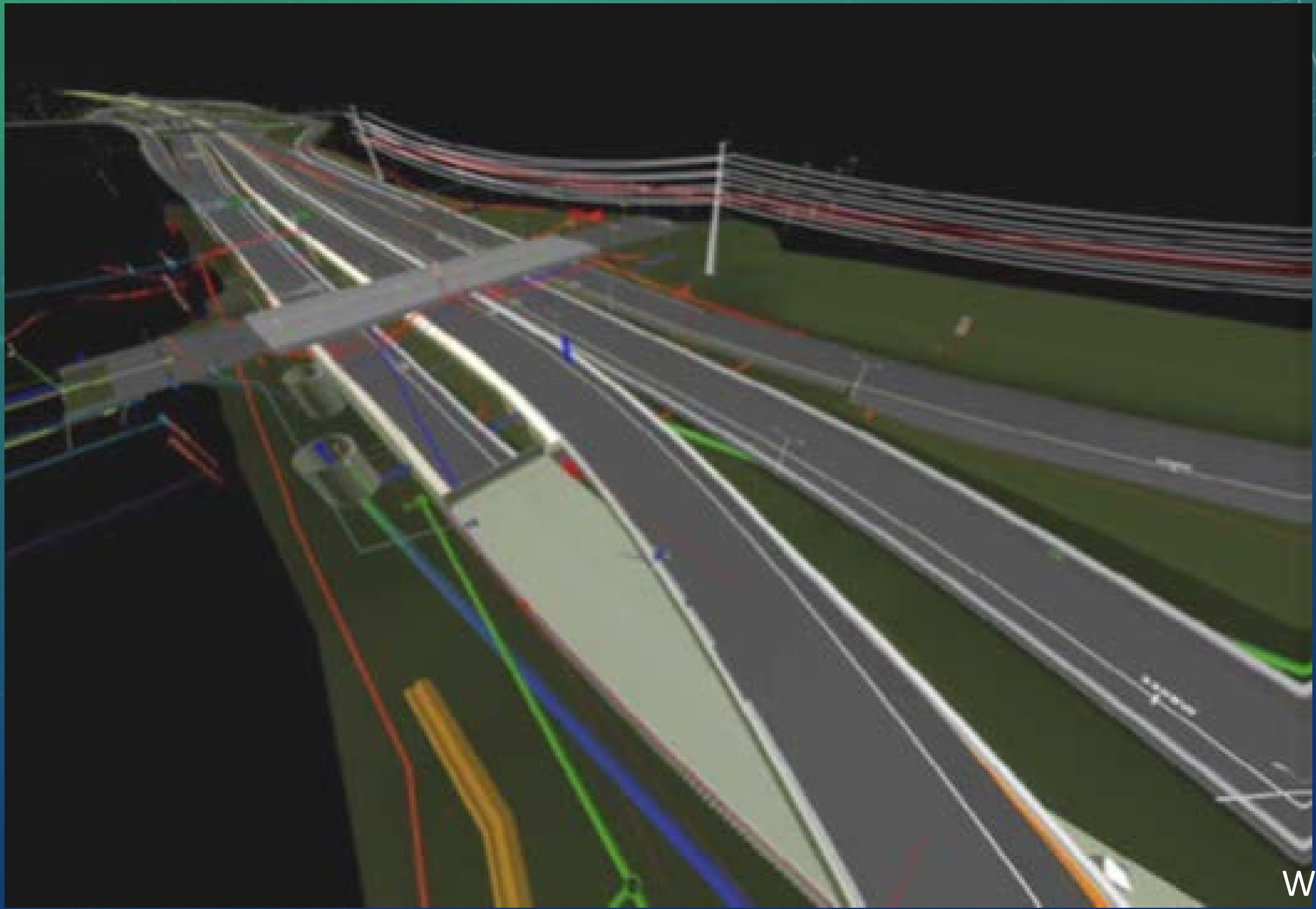
WORK FLOW COMPARISON





3D DESIGN AND VISUALIZATION

Mitchell Interchange I-94/I-43 Corridor

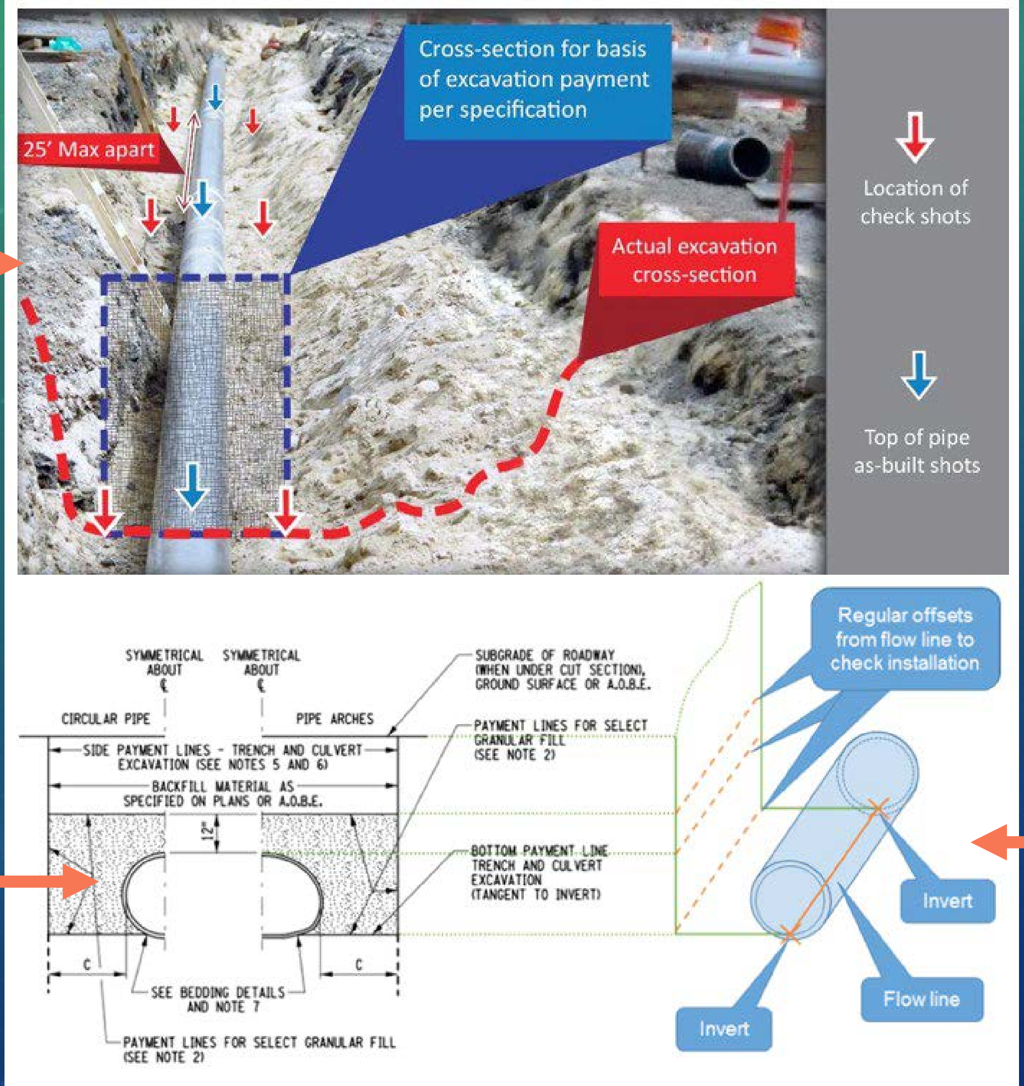


WisDOT, 2012

2D DRAWING VS 3D DESIGN/MODEL

Photos

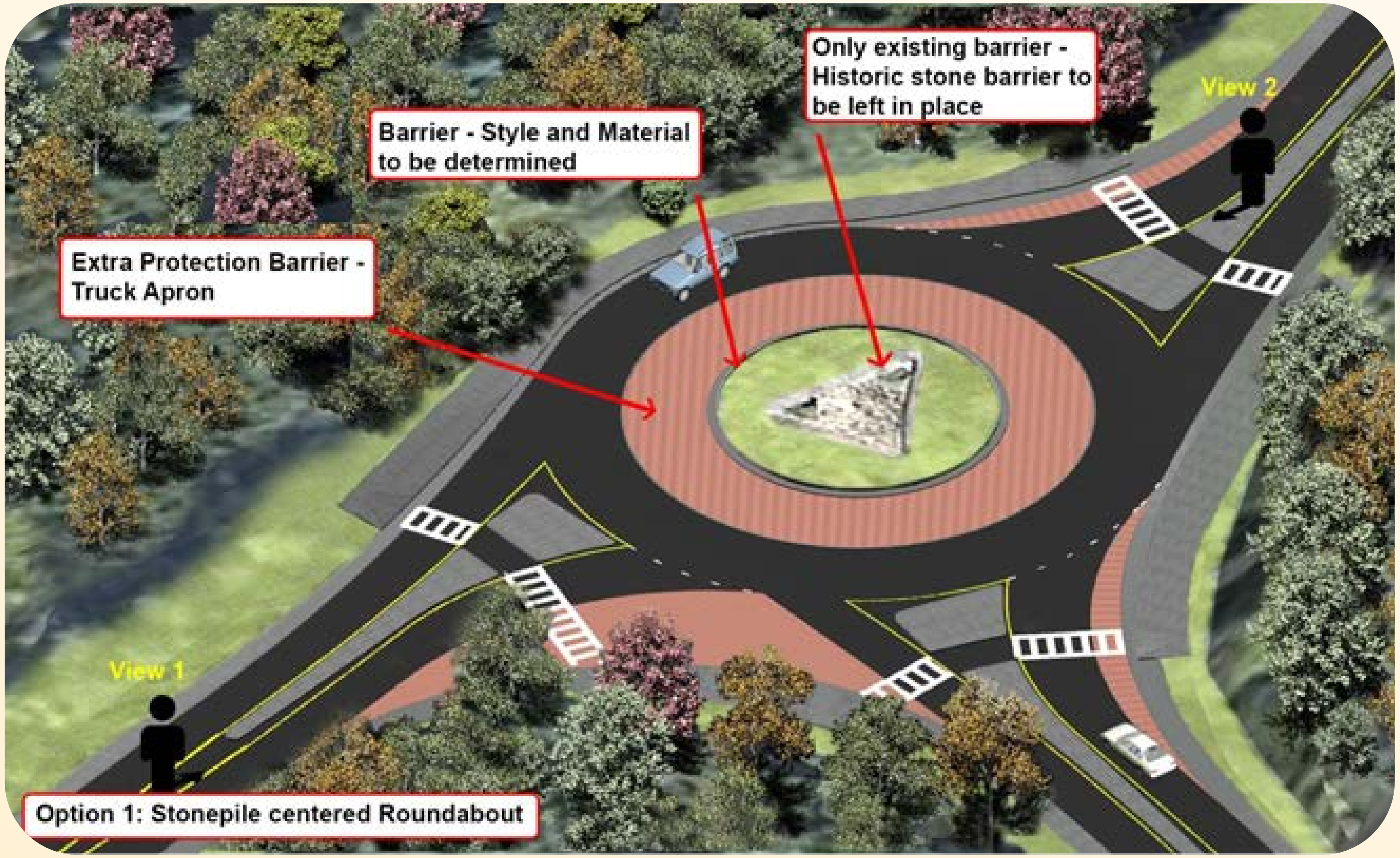
2D Drawing



3D Design/Model

IICTG.org

3D MODELING THRU ALL PHASES



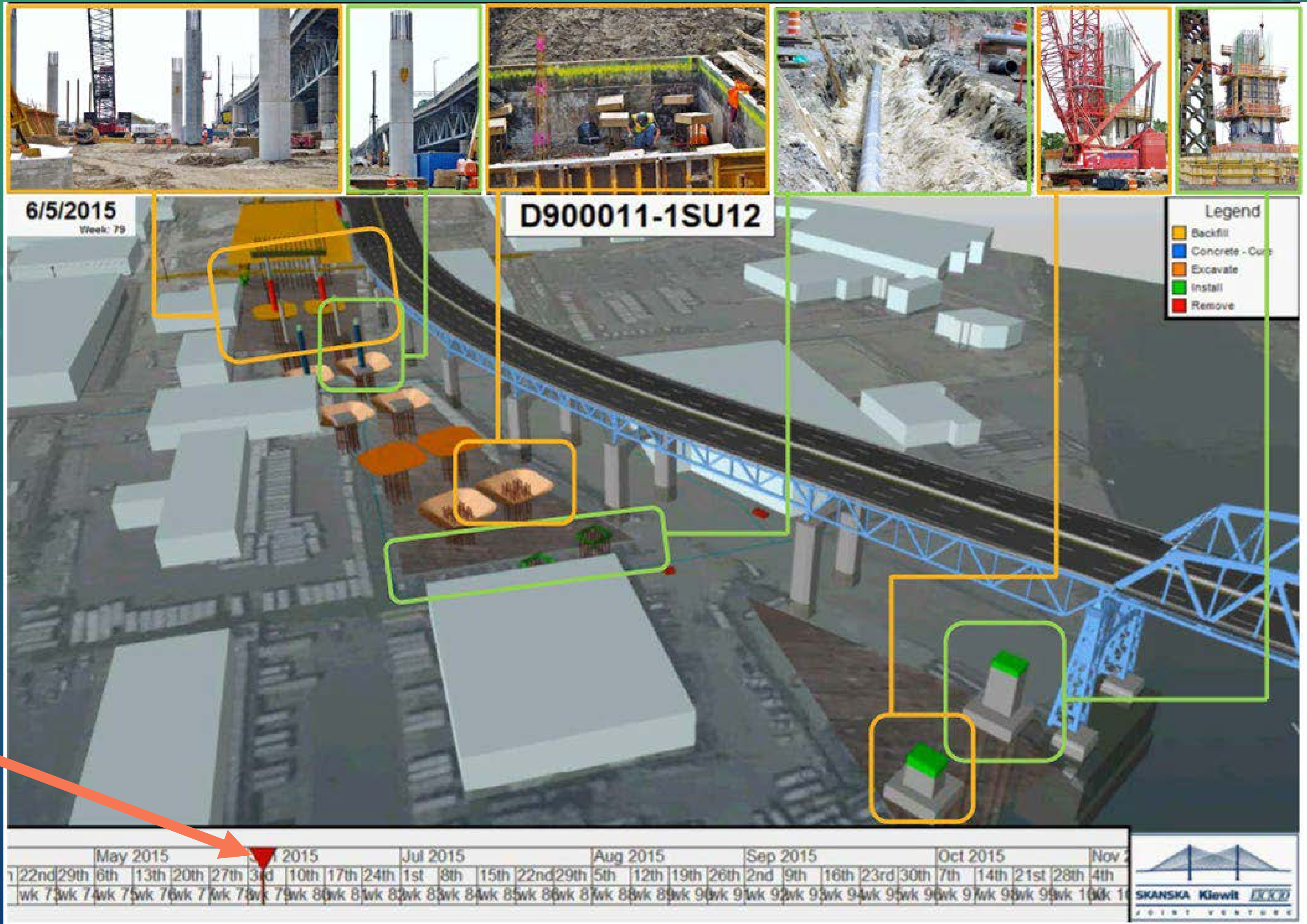
2D Drawing/Photo

3D Design/Model

AS-BUILT 4D MODEL AND SITE PHOTOS

Photos

4D Model for Specific date



IICTG.org

KEY BENEFITS

- More accurate construction documents and 3D as-built plans
- Visualization for engineering analysis and communication with the public
- Detection of issues before construction, conflict resolution applications (i.e. utilities)
- Automated Machine Guidance (AMG), quantities calculations, etc.

CHALLENGES

- How to quantify implementation cost?
- Direct method to document ROI?

Challenge	Solution Example
Implementation Cost	• Begin with 3D design for mega/large projects, then work agency wide implementation • Begin with smaller projects and build on experience

CHALLENGES

Challenge	Solution Example
Lack of Standards, Interoperability	• Meetings with industry associations and contractors • Collaboration with technology vendors, equipment manufacturers, etc.
Specialized Training and Software	DOTs handle transition and training individually since it requires organizational and cultural changes

CHALLENGES

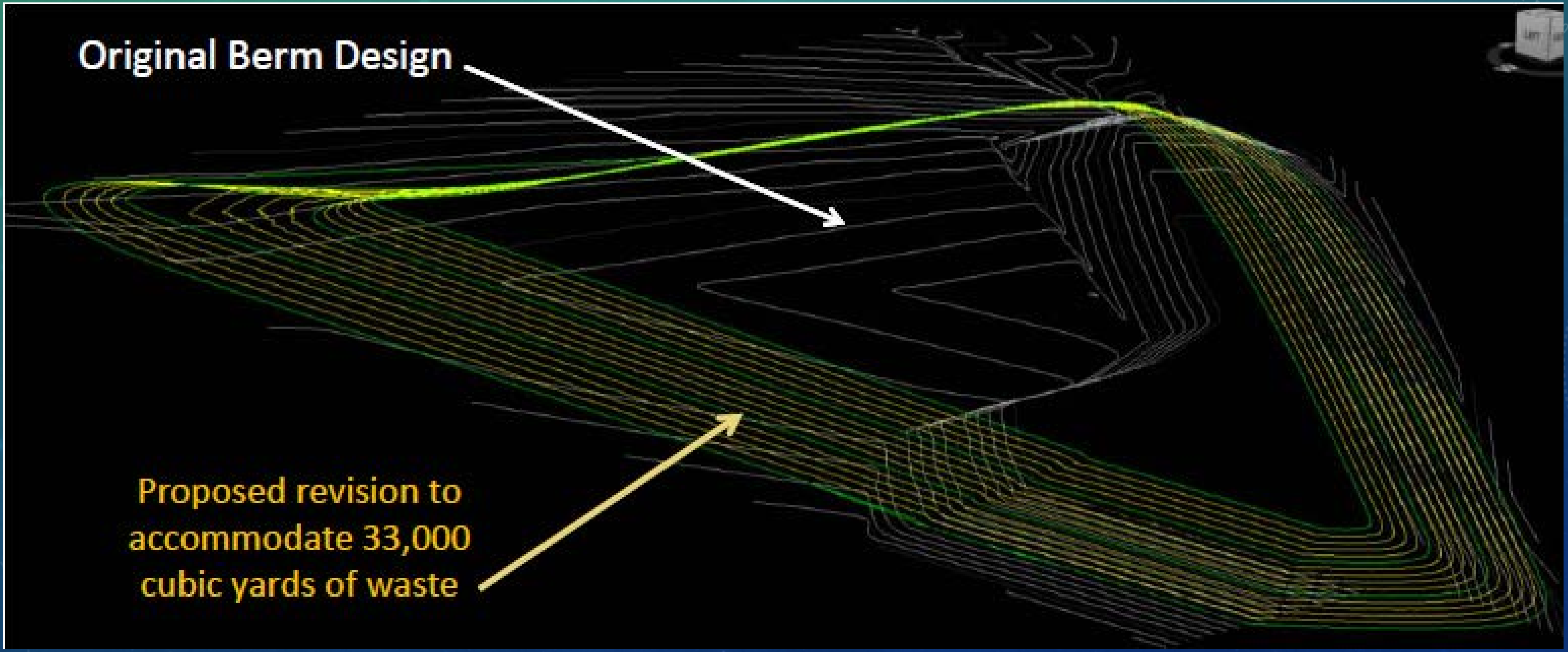
Challenge	Solution Example
Contractual and Legal Issues	Incremental steps towards this goal, e.g.: • Replaced 2D plans with PDF sealed with a digital signature • Release 3D models for information only, with disclaimers
Model Certification/ Review	Design-construction reviews for megaprojects with designers, consultants, construction, and industry personnel

CONSTRUCTION AUTOMATION

ICTG.org

MODEL USE DURING CONSTRUCTION

Model correction to avoid excessive waste



WisDOT

MODEL USE DURING CONSTRUCTION

Model and as built shots used to mediate disputes between contractors

GRADE CONTROL WITH GPS AND UTS

GCS900

Grade Control System

From 2D to 3D

GCS400

UTS

Courtesy Trimble

IICTG.org

AUTOMATED SCRAPER

Liebherr

3D MILLING

GCS900
Grade Control System

Trimble

ICTG.org

3D UTS HMA PAVING

Trimble

ICTG.org

3D UTS HMA Paving

ICTG.org

3D UTS PCCP Stringless Paving

BENEFITS

- Better control of quantities
- Increased productivity
- Increased accuracy and precision
- More uniform surfaces
- Reduced surveying cost and time
- Fuel savings
- Increased safety

COST AND ROI

- Cost and ROI information is scattered
- Case studies available are at a project level, not representing agency wide figures.
- Direct method to document ROI?
  - DOTs: construction bids
  - Contractors: quantities overruns

CHALLENGES

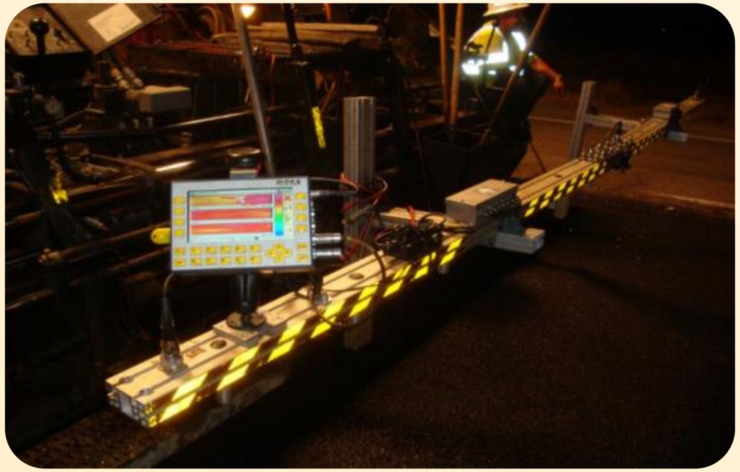
Challenge	Solutions
Lack of 3D Models	• Contractors "reengineer" 3D model from 2D plans • Pilot projects to evaluate 3D surface model standards and data flows • Some DOTs deliver 3D surfaces/models from design and support AMG usage by contractors
Lack of Training / Education	• Pilot projects to illustrate utilities and benefits • For all parties: designers, inspectors (i.e. GPS equipment calibration), equipment operators, etc.

IICTG.org

CHALLENGES

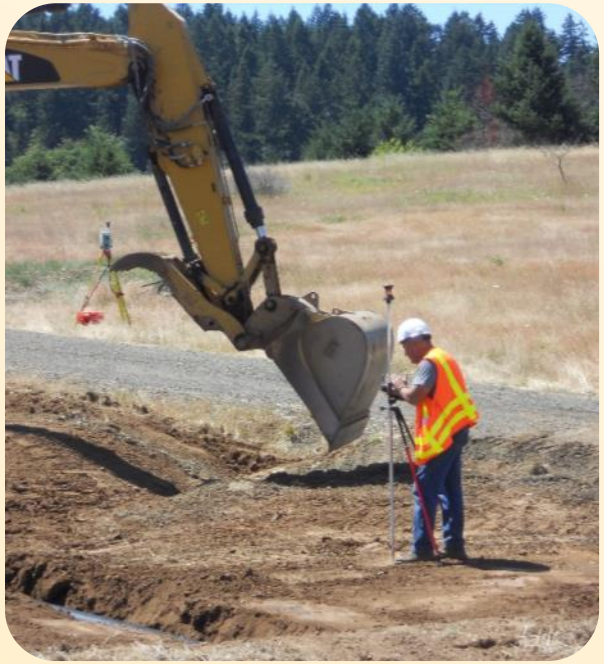
Challenge	Solutions
Lack of Specifications and Inspection Procedures	Specification and special provisions have been developed by DOTs, many based on pilot studies. • NCHRP 10-77: This project is to develop AMG guidelines • AASHTO's AMG Quick Reference Guide

REAL TIME MONITORING & INSPECTION



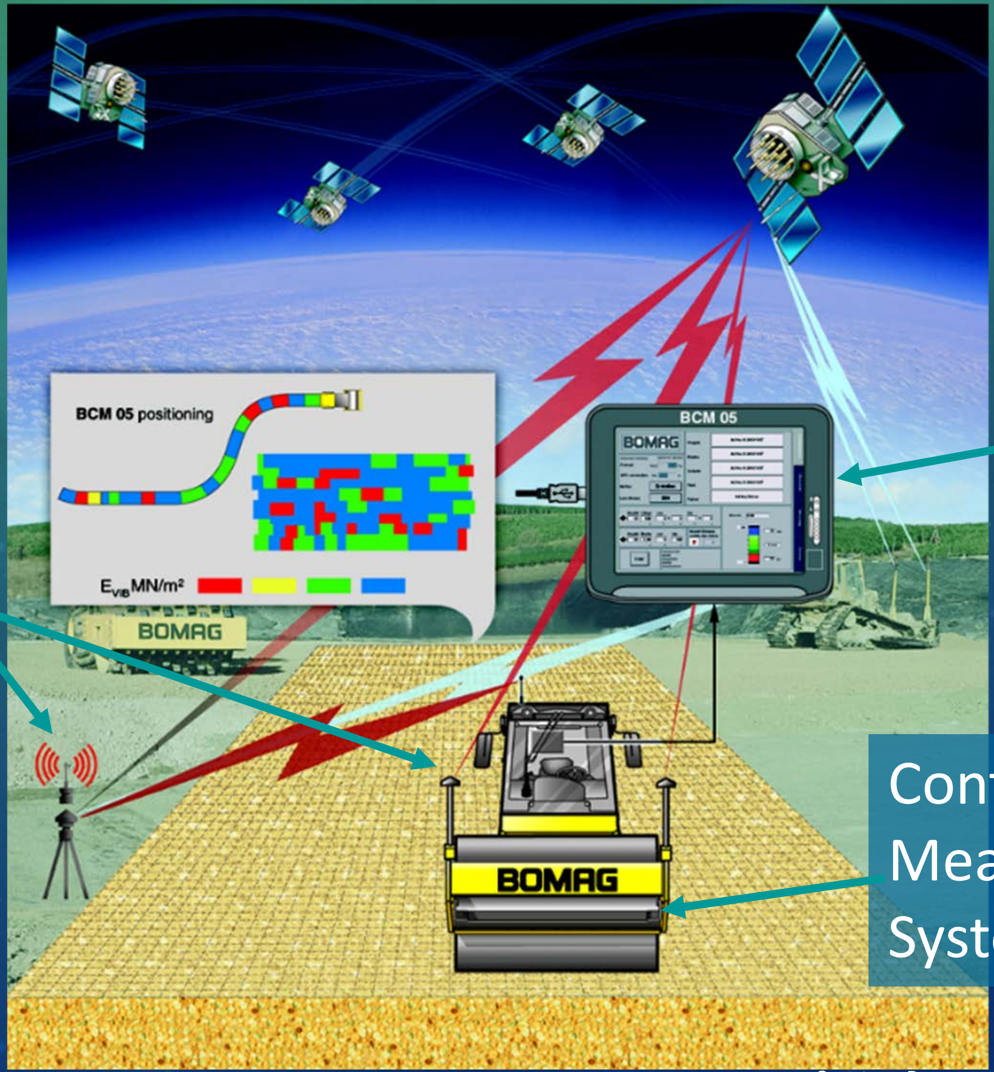
IICTG.org

REAL TIME MONITORING & INSPECTION



INTELLIGENT COMPACTION

Global Position System (GPS)



Courtesy Bomag

Onboard Report system

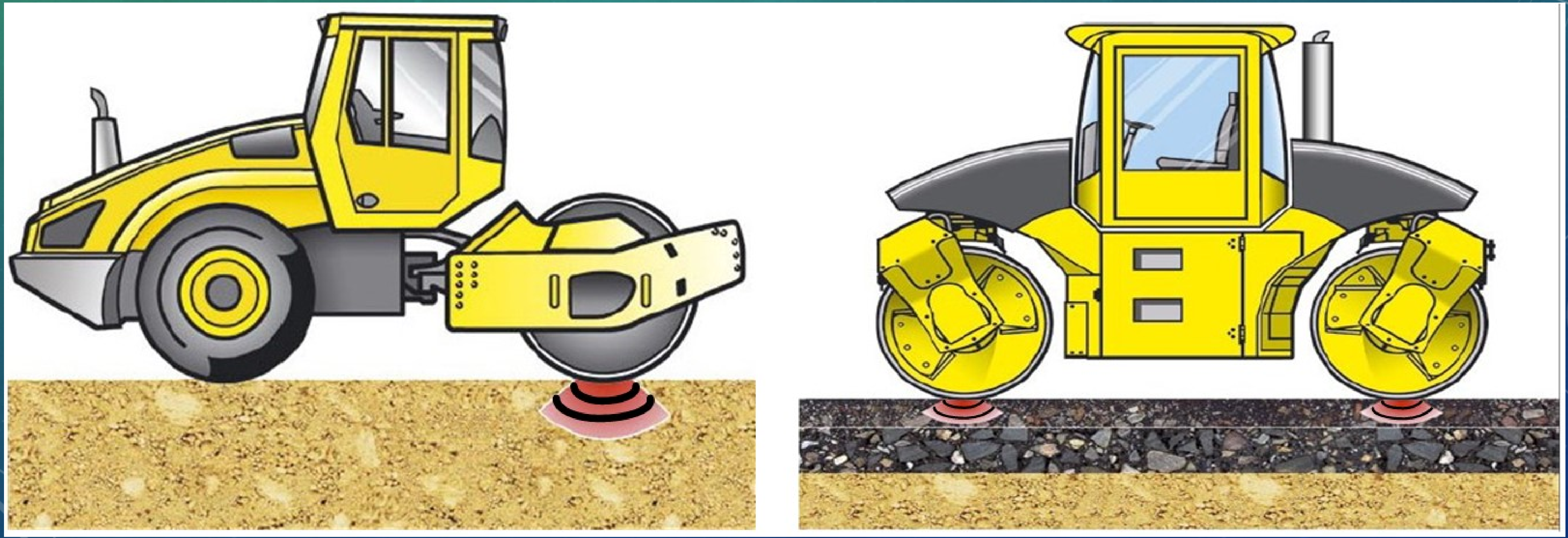
Continuous Measurement System

Courtesy of Caterpillar

Soils IC

ICTG.org

SOILS IC VS. ASPHALT IC



IICTG.org

SINGLE DRUM IC ROLLERS

Ammann-Case

Caterpillar

HAMM-Wirtgen

Soils and Subbase

BOMAG

Dynapac-Atlas Copco

Sakai

DOUBLE DRUM IC ROLLERS

BOMAG

Hamm-Wirtgen

Dynapac-Atlas Copco

Asphalt

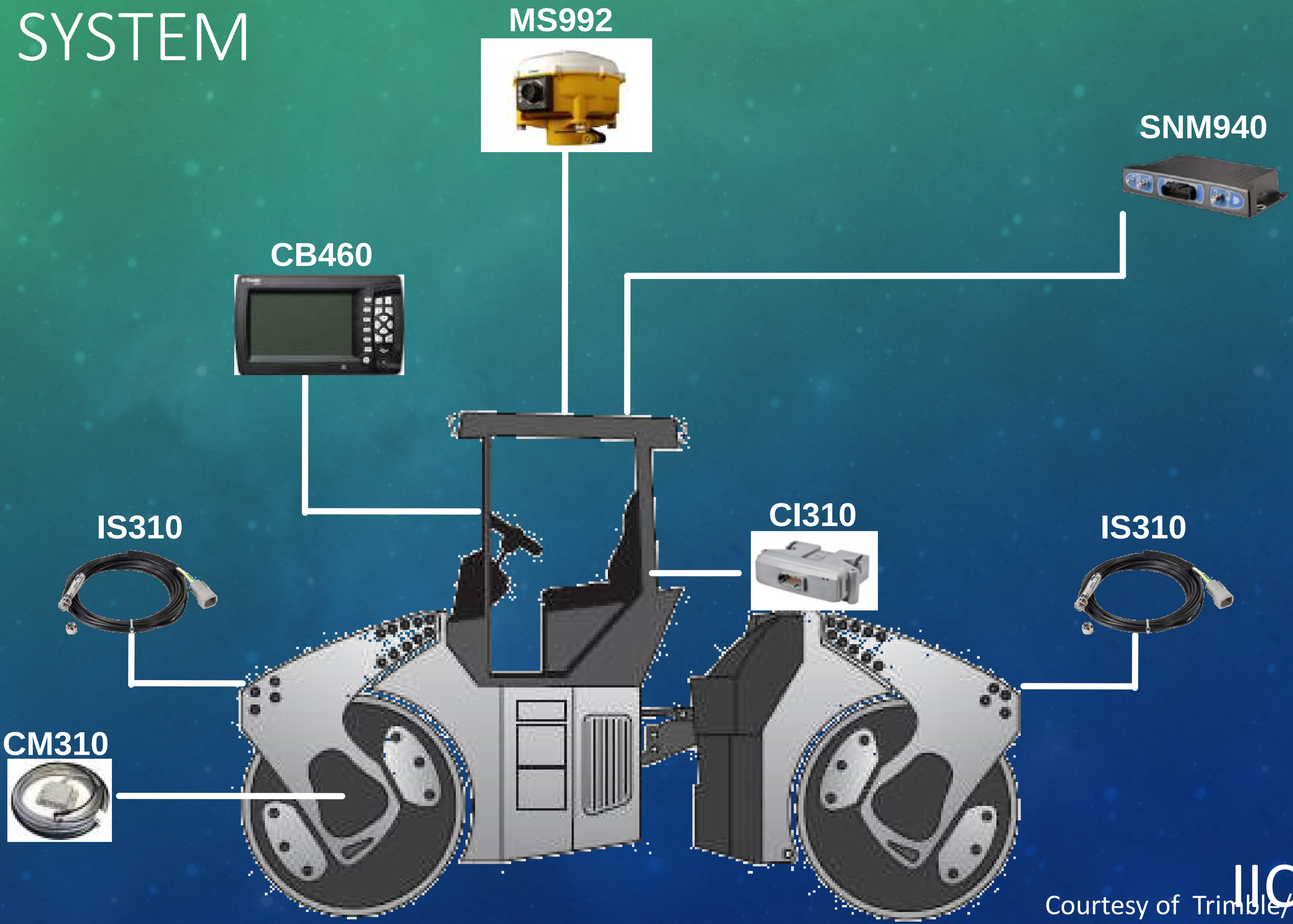
Caterpillar

Sakai

Volvo

IC RETROFIT SYSTEM

- CCS900



Courtesy of Trimble/SITECH

GPS Antenna

GX-60

MCi-3 and
Satel Radio

Infrared
Temperature
Sensor

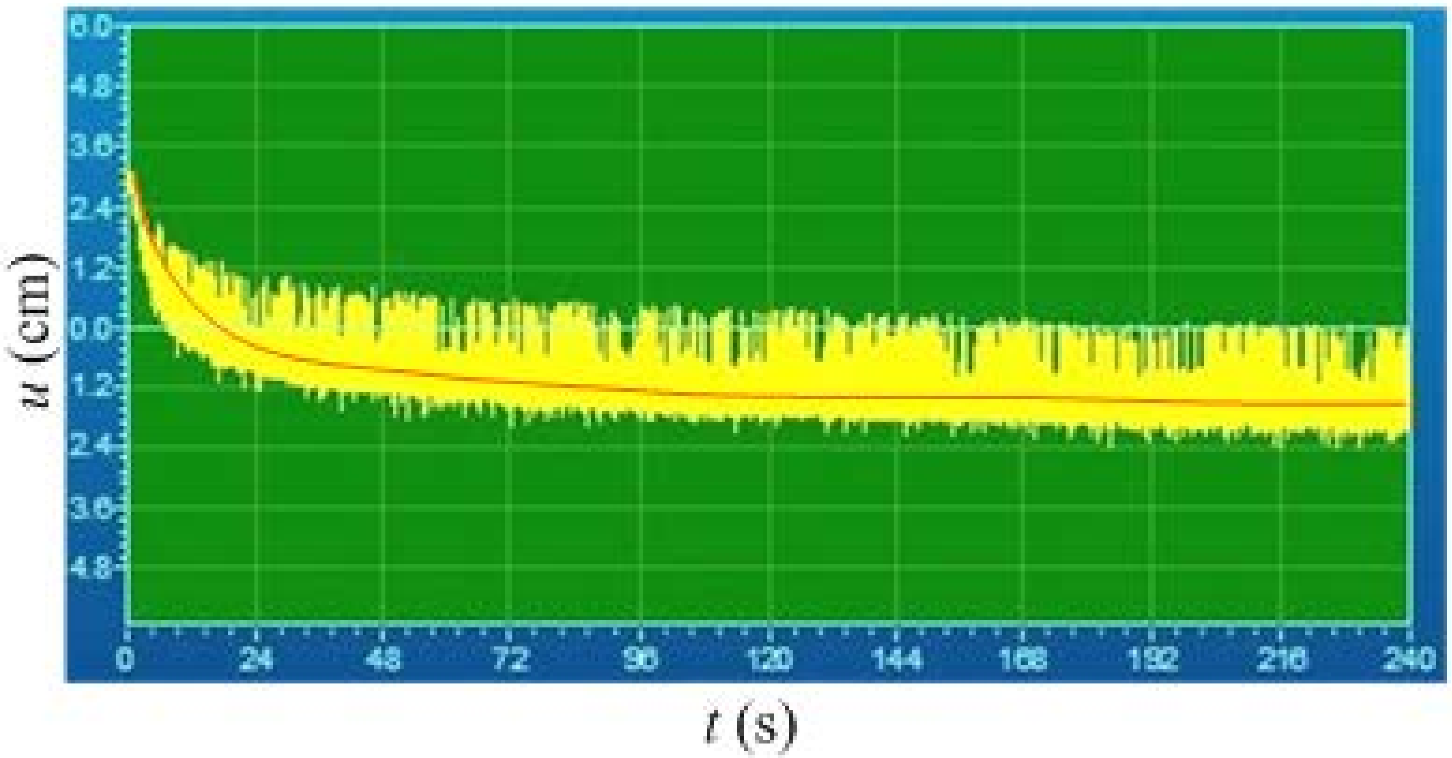
Accelerometer

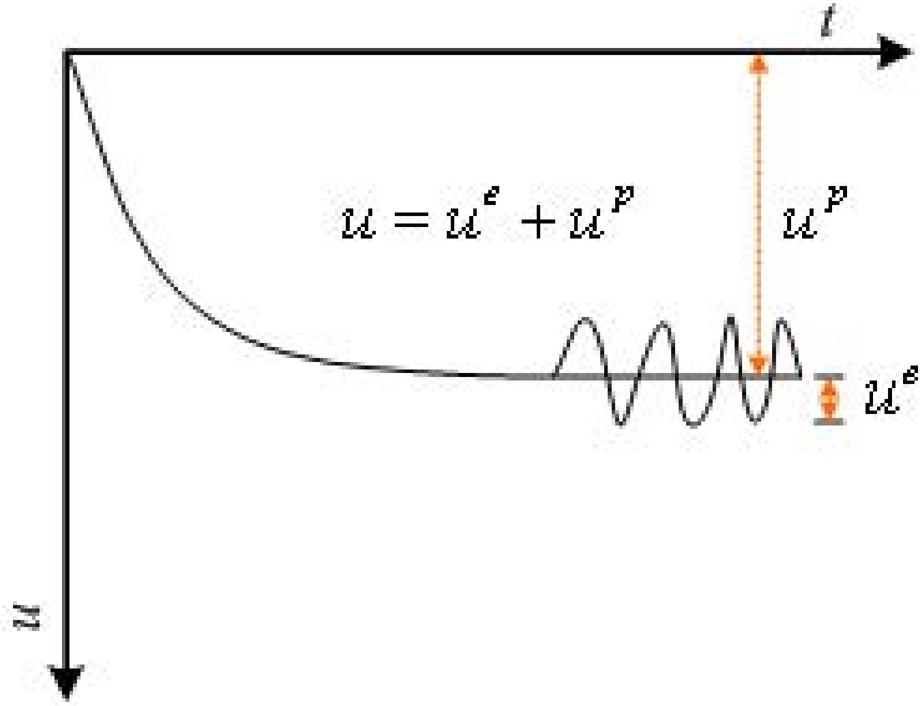
Courtesy of Topcon/RDO

ICMV

Intelligent Compaction Measurement Value

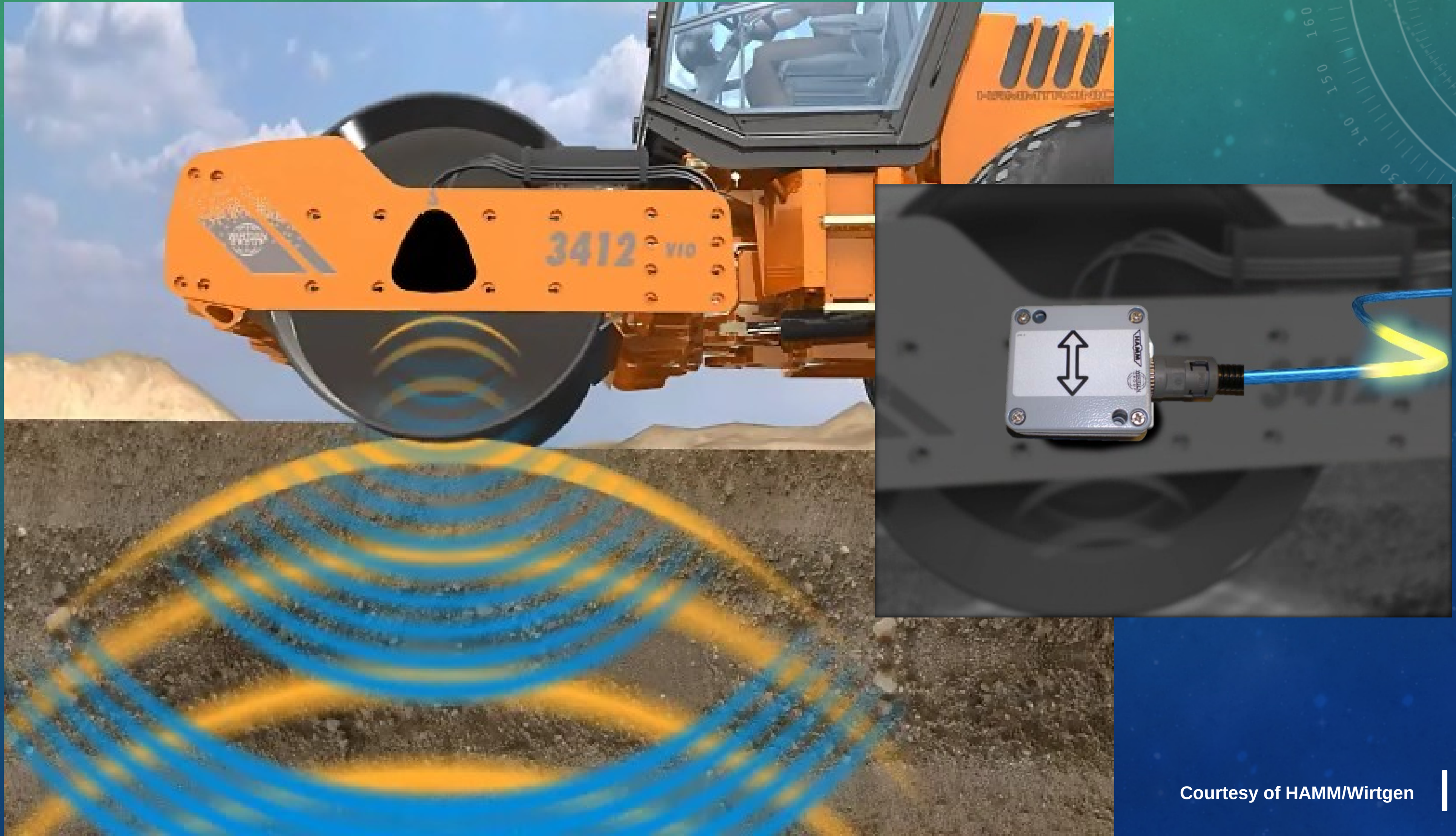
DEFORMATION OF MATERIALS DURING COMPACTION





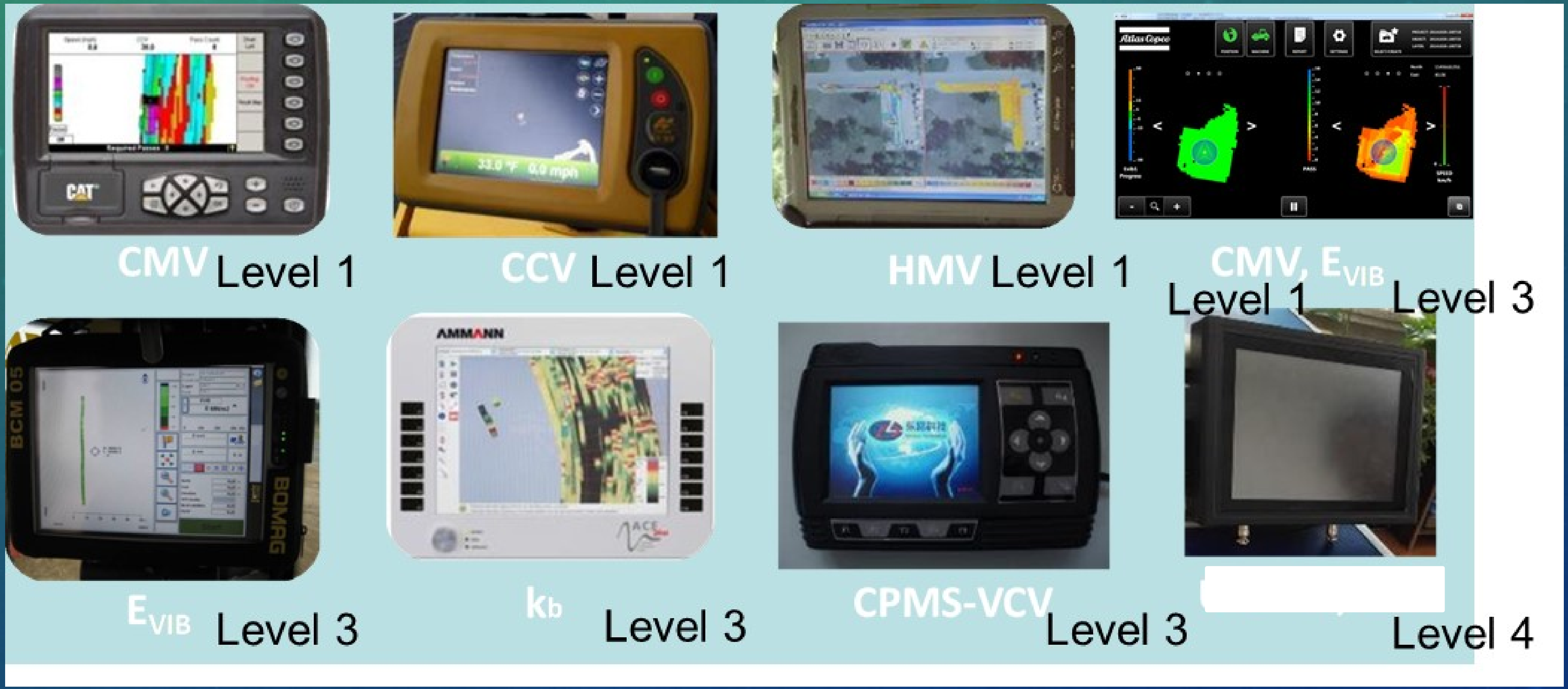
Plastic + Elastic Deformation

ACCELEROMETER-BASED ICMV



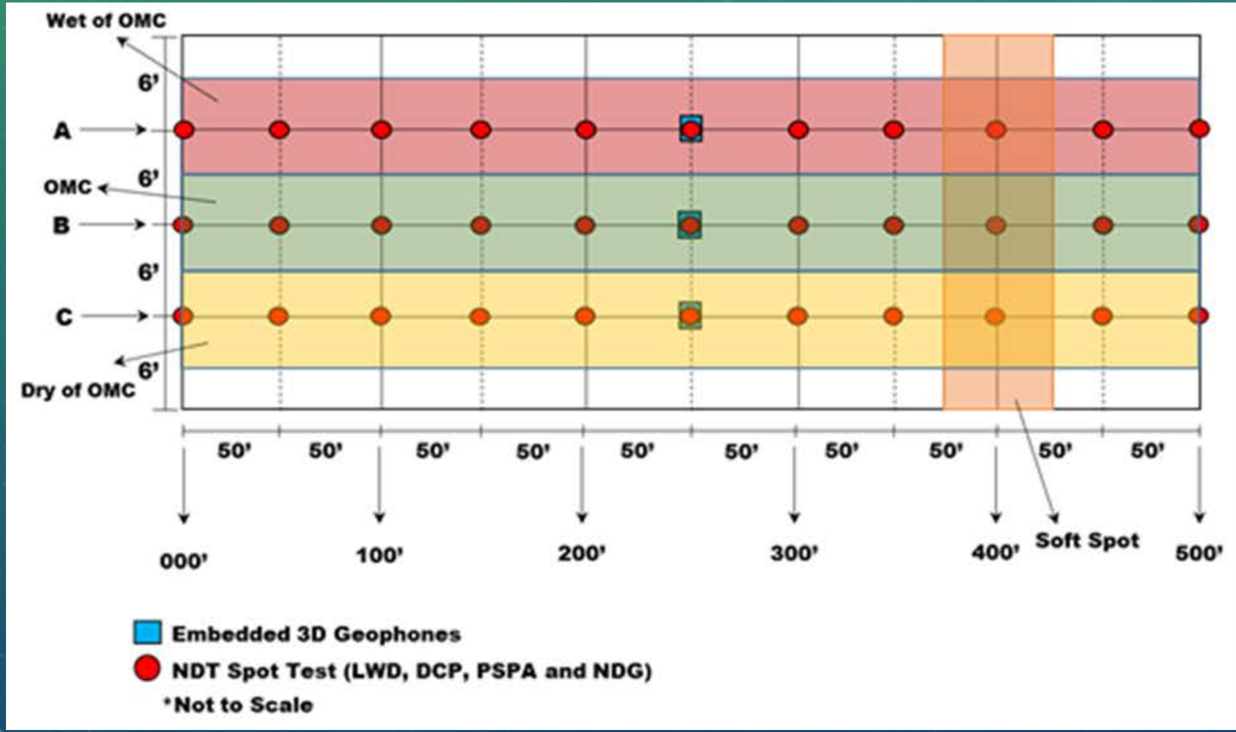
Courtesy of HAMM/Wirtgen

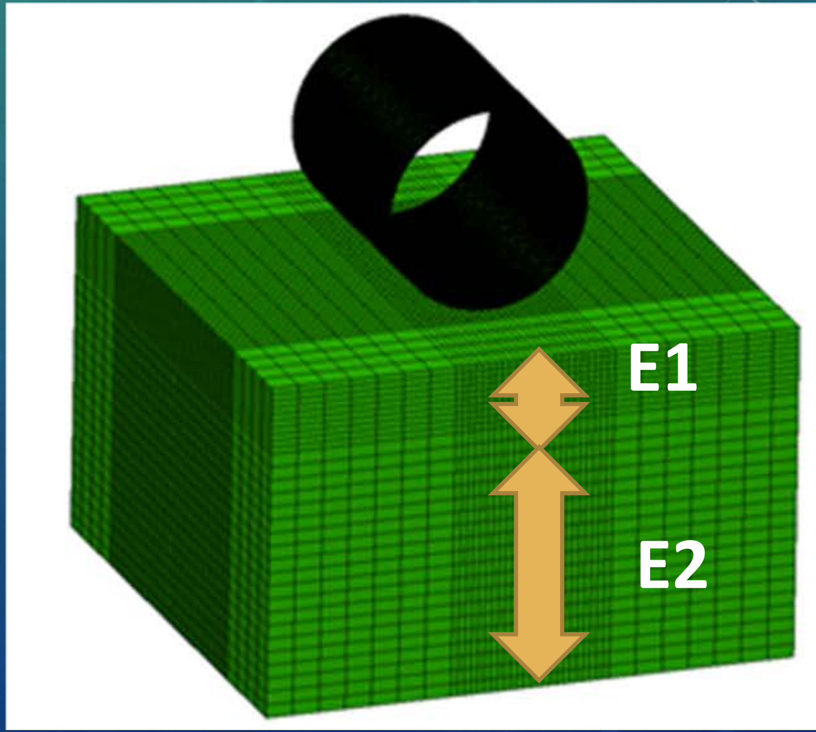
VARIOUS ICMV



US NCHRP 24-45 IC STUDY

2015 - 2018

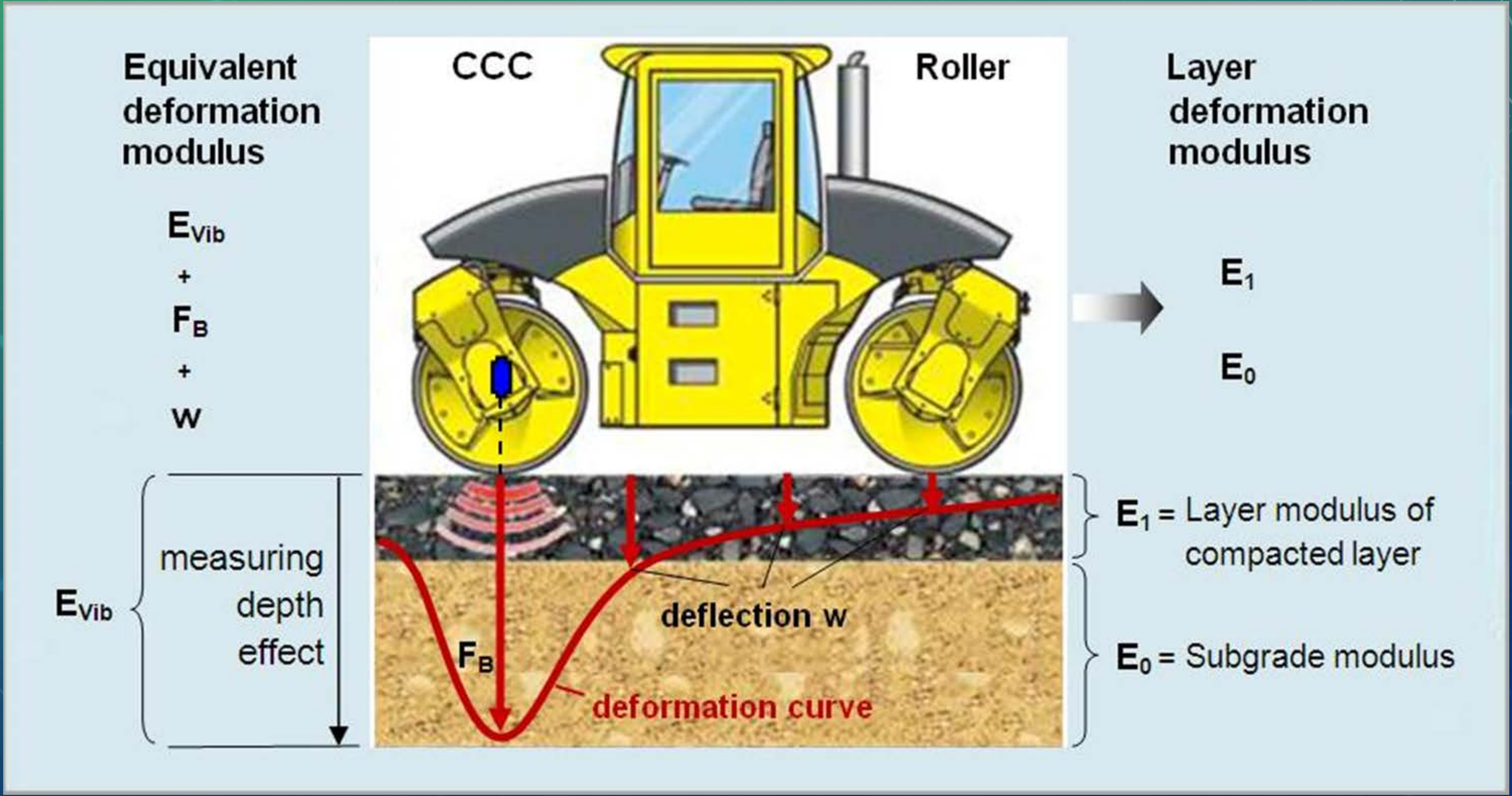




De-Coupled Layer Moduli

IICTG.org

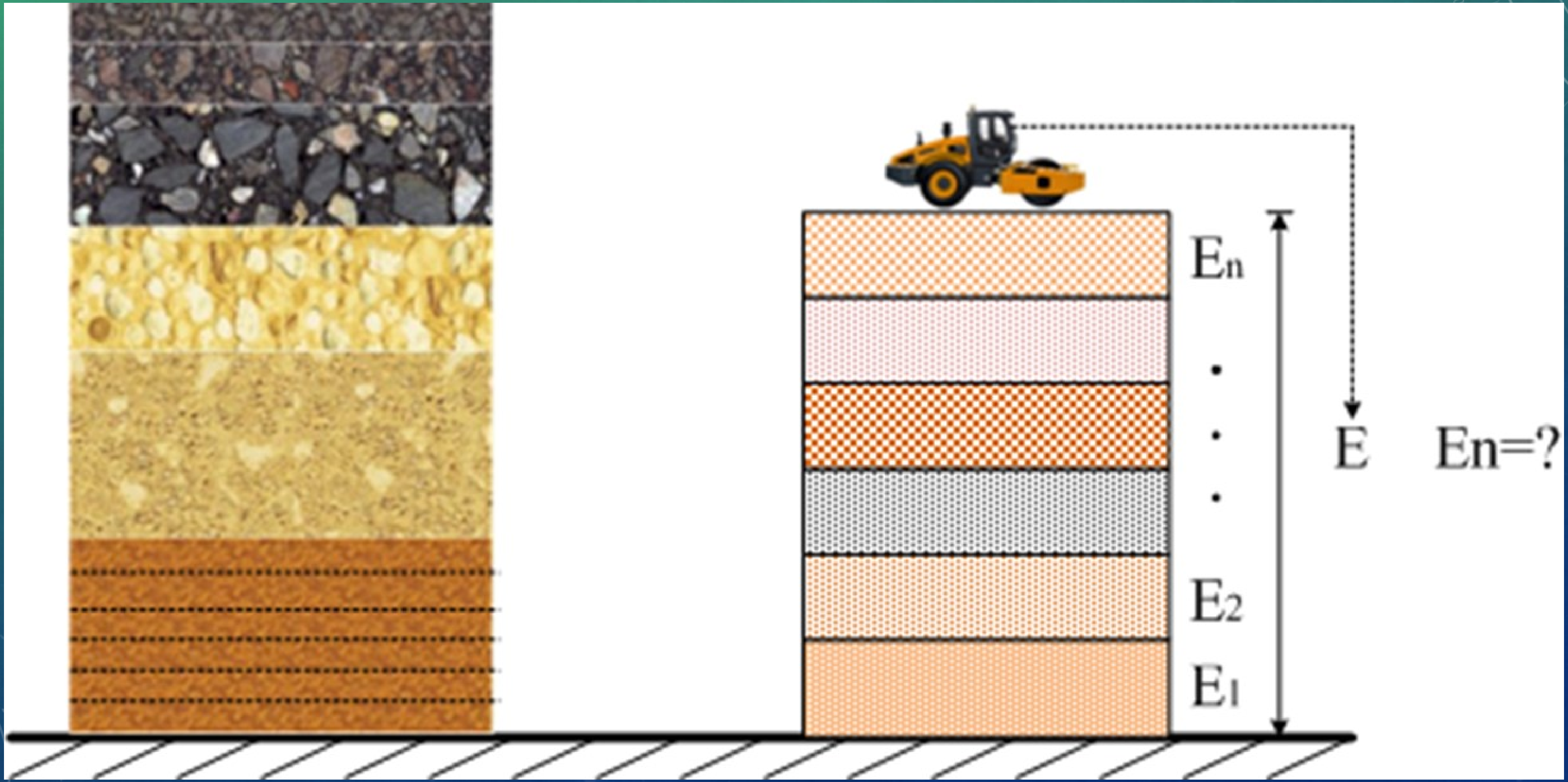
DE-COUPLED LAYER MODULI



Courtesy of Bomag

IICTG.org

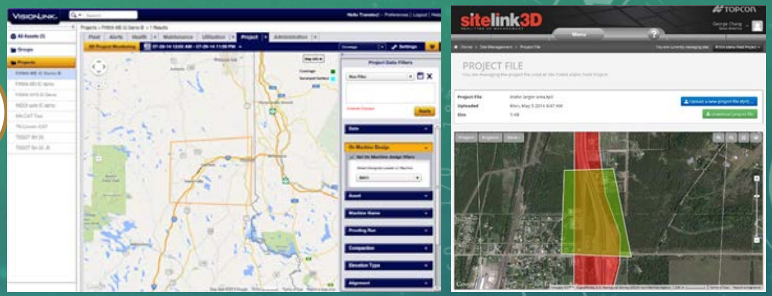
LAYER MODULI - FROM THE GROUND UP



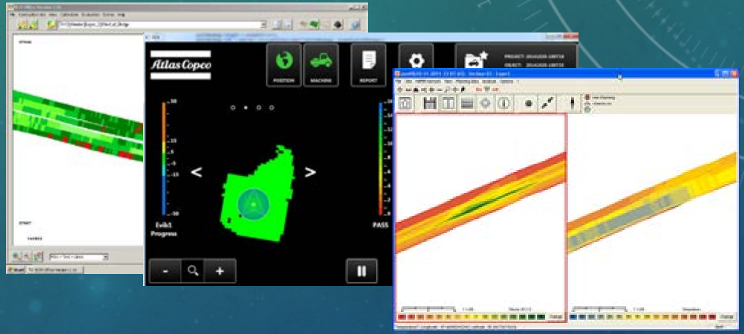
IC/TP data

Automatic

Vendor's cloud Server



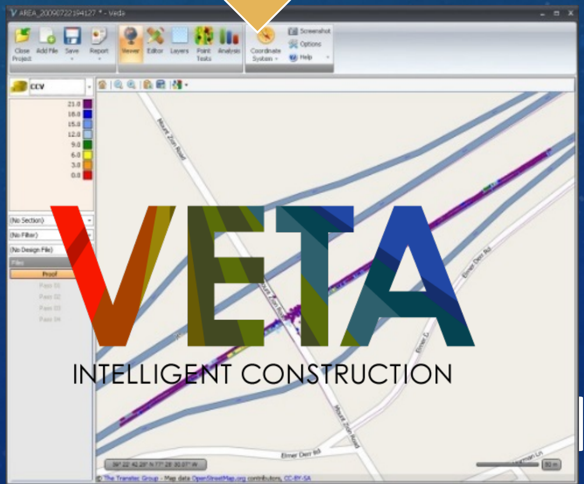
Manual USB



Data Export USB, email, etc.

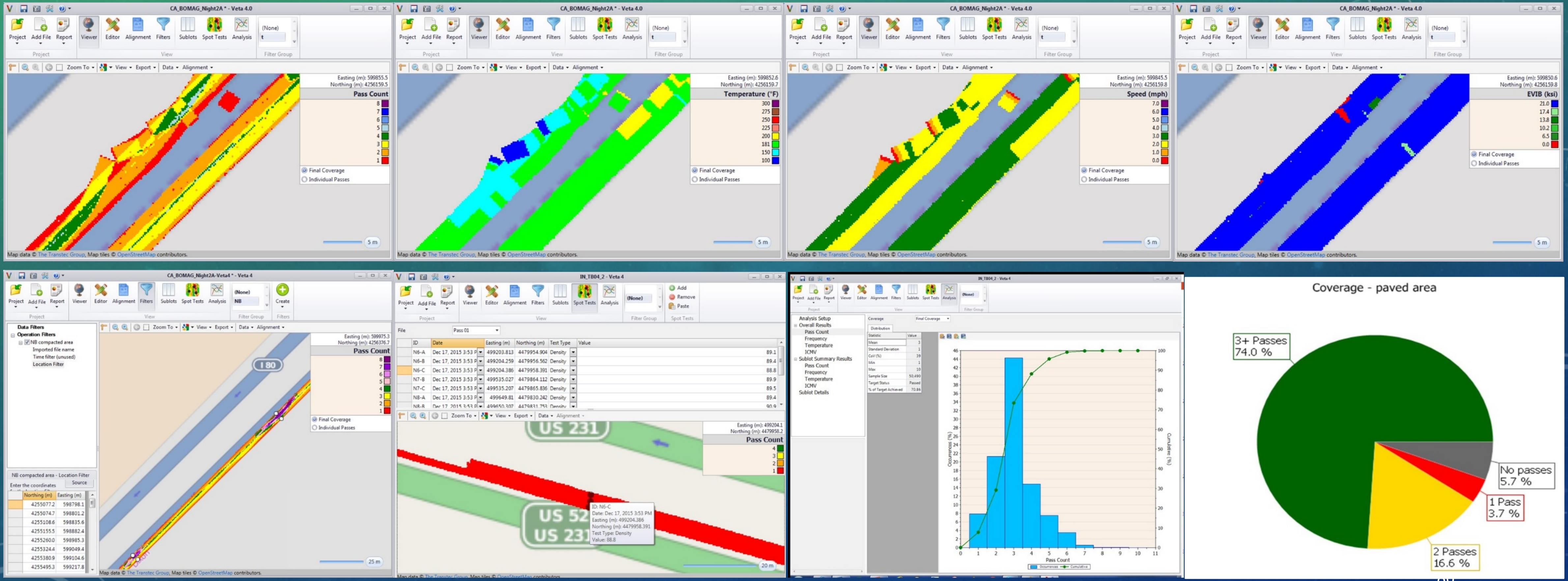
Spot test data

Manual



ICTG.org

STANDARD VETA ANALYSIS



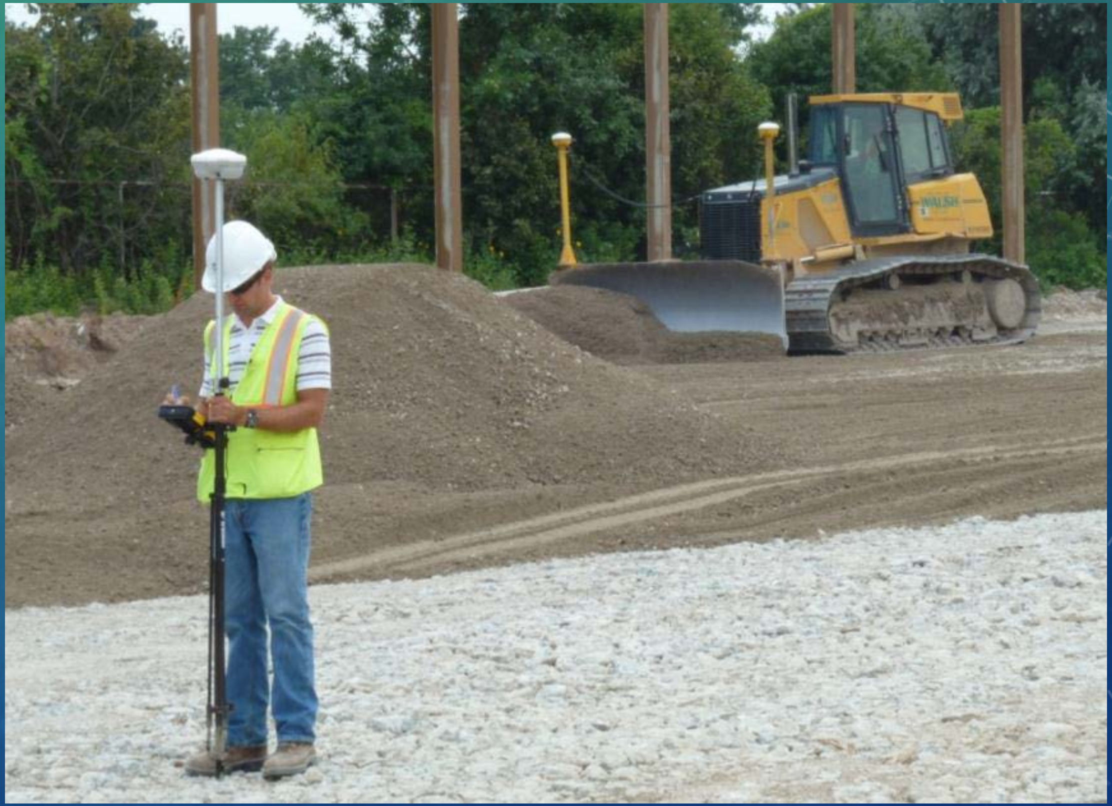
GPR TO MEASURE HMA DENSITY

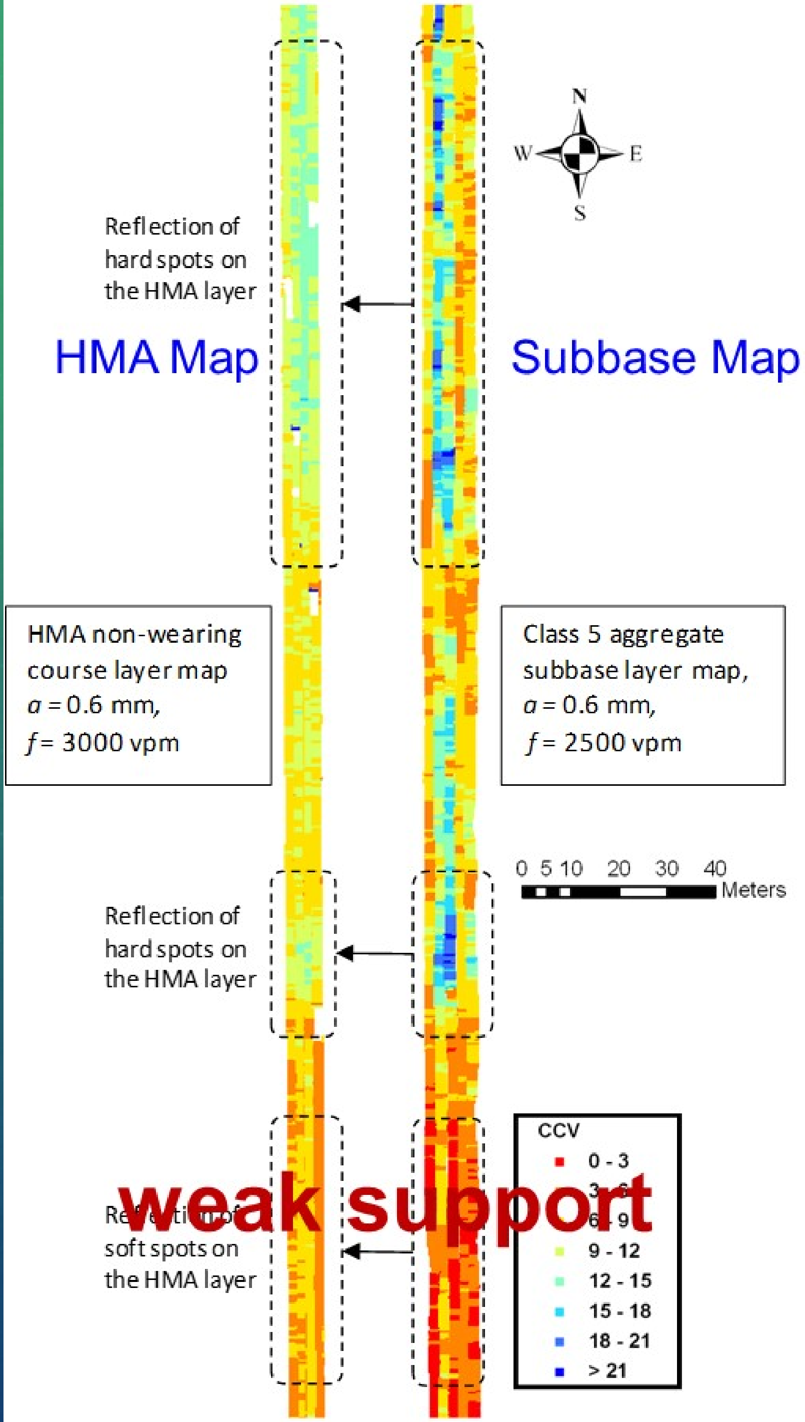
IICTG.org

REAL TIME SMOOTHNESS

INSPECTION WITH ROVER

- Grade checks
- Structures
  - Wall alignments
  - Sign bridge footings
  - Structure excavation
- Pavement marking layout
- Pay quantity measurements

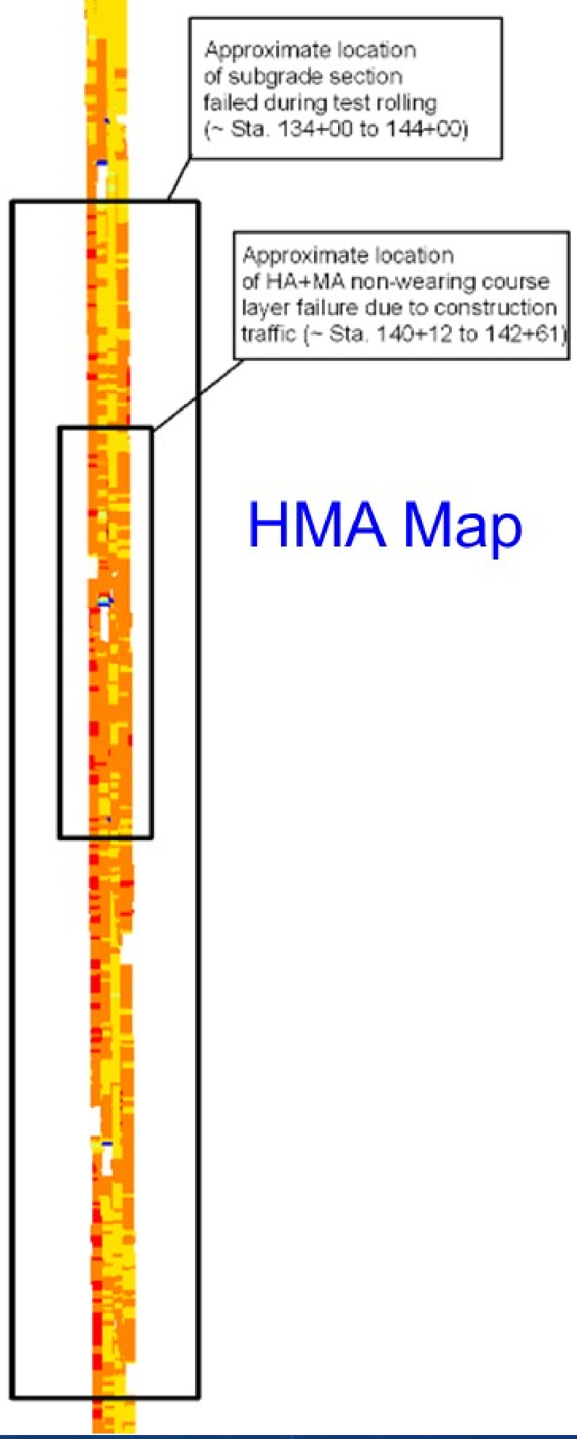




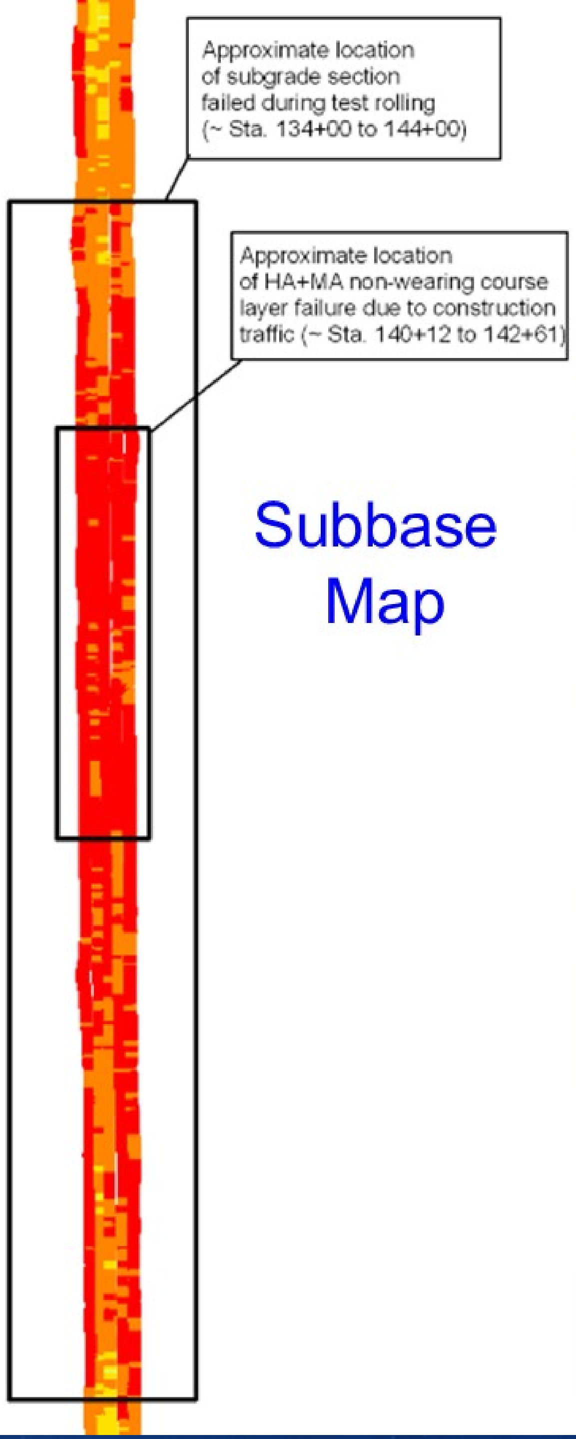
Pre-Mapping Subbase

Asphalt Compaction

Premature Failure

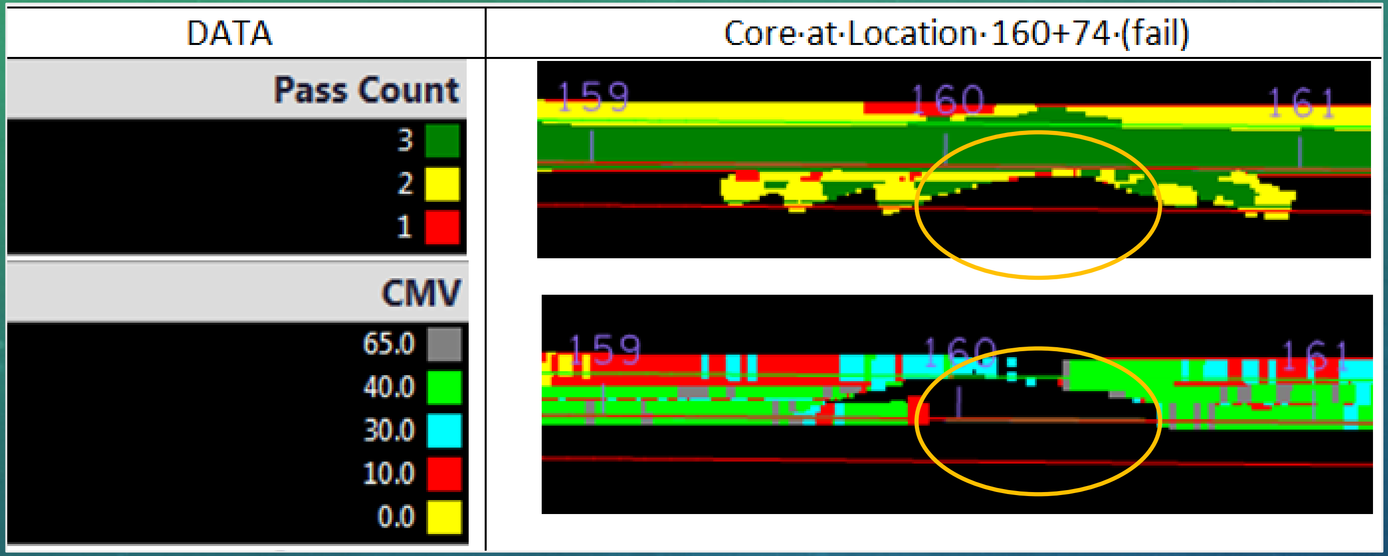


HMA Map

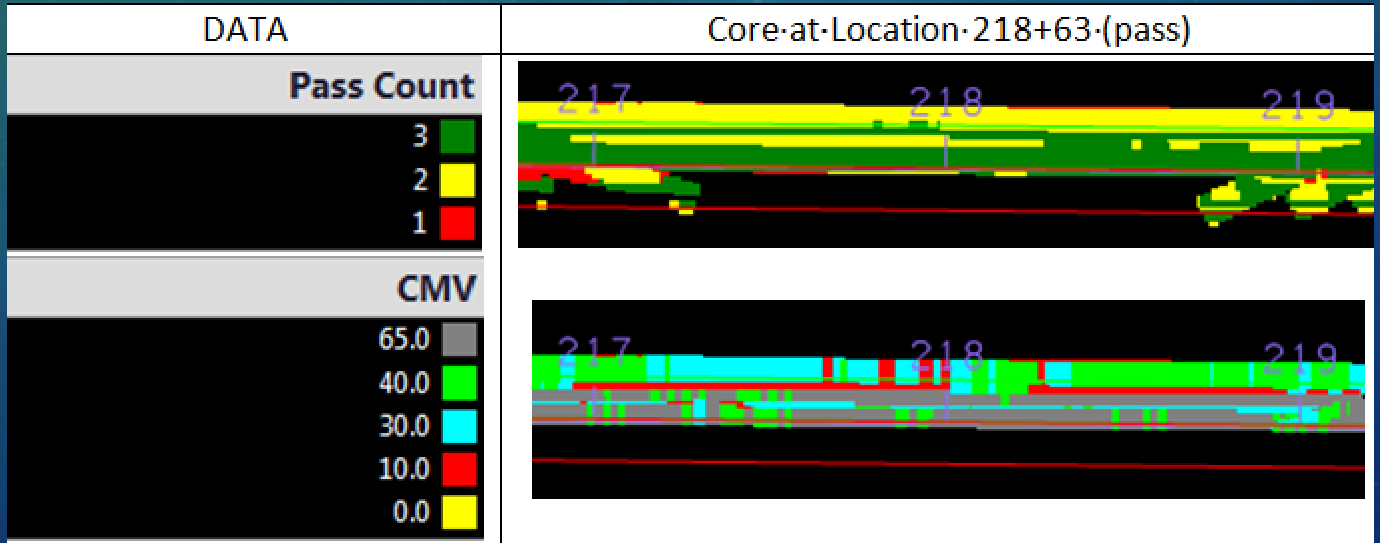


Subbase Map

IC IDENTIFIES CAUSES OF FAILURES



Failed density
due to static passes

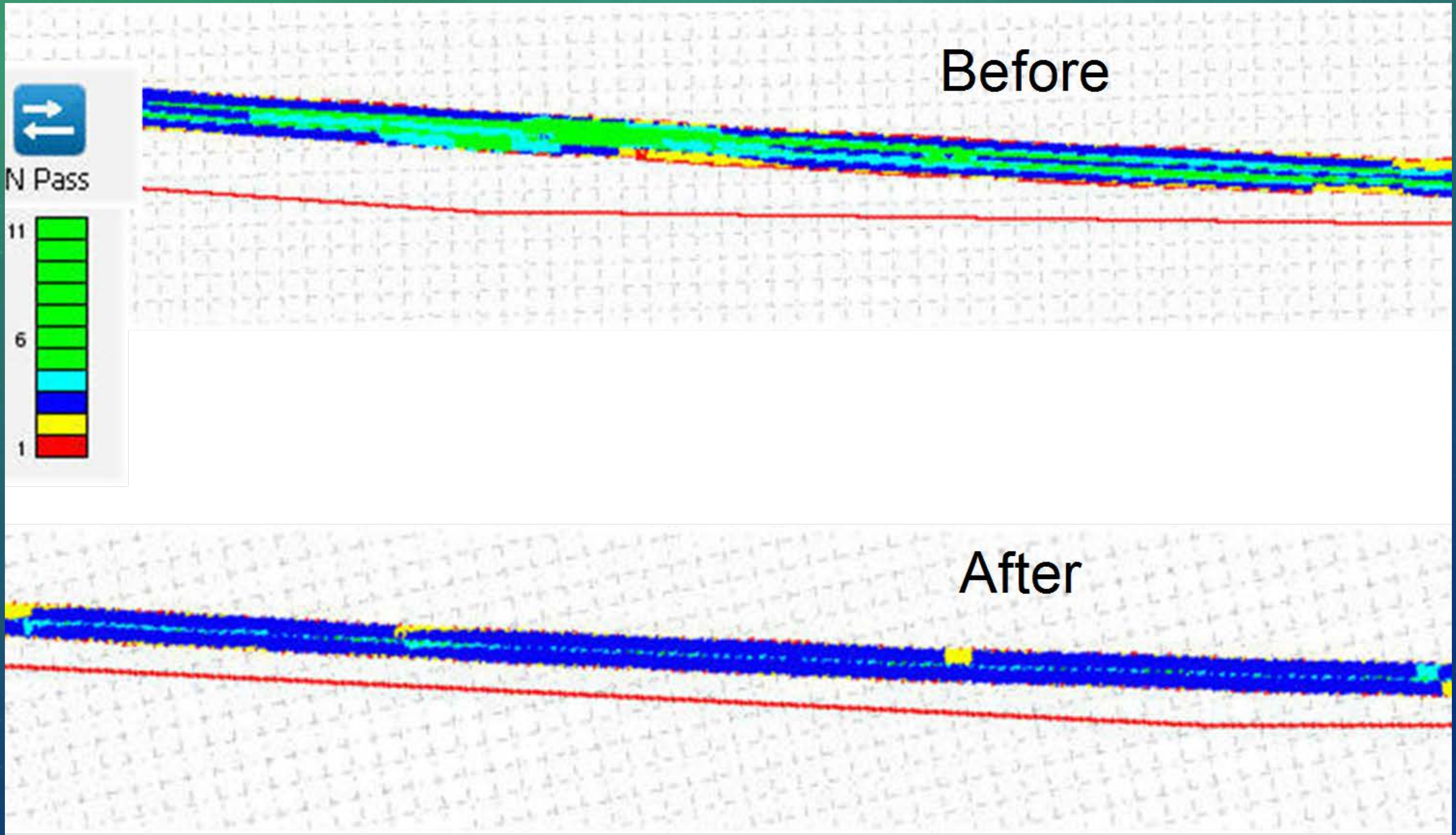


Passed density
with vib passes
Aided using IC

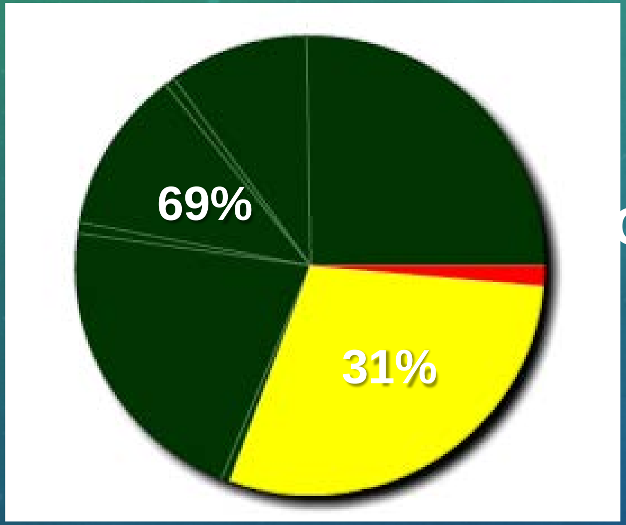
MNDOT

IICTG.org

IC BENEFITS



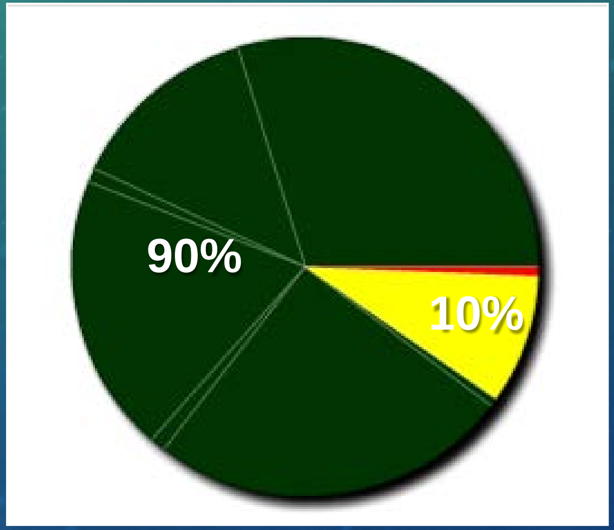
IC IMPROVES CONSISTENCY



Lift 1 without IC

< 3 Passes: 31 %
≥ 3 Passes: 69 %
COV : 71%

30% Increase in Compaction Efforts



Lift 2 with IC

< 3 Passes: 10 %
≥ 3 Passes: 90 %
COV: 55%

Courtesy of MNDOT

BENEFITS

- Less coring of new and existing pavements/structures, labor intensive tests
- Improved materials quality with faster feedback, and continuous and more complete coverage
- Uniformity and consistency
- Fuel/operation savings

BENEFITS

- Increased efficiency and productivity
- Improved communication
- Safety

CHALLENGES

Cost and ROI information associated with these technologies varies widely

- Not used routinely by DOTs
- Still undergoing R&D

Challenge	Solutions
Technology and Implementation Cost	Education and unbiased publications with project data documenting cost and time savings.

CHALLENGES

Challenge	Solution Example
Lack of Awareness	Demonstrations and publications by national agencies such as FHWA, NCHRP, SHRP2, etc.
Lack of Training / Education	• Pilot projects to illustrate utilities and benefits • Case studies • Customized workshops focusing on advanced technologies for field technicians and inspectors

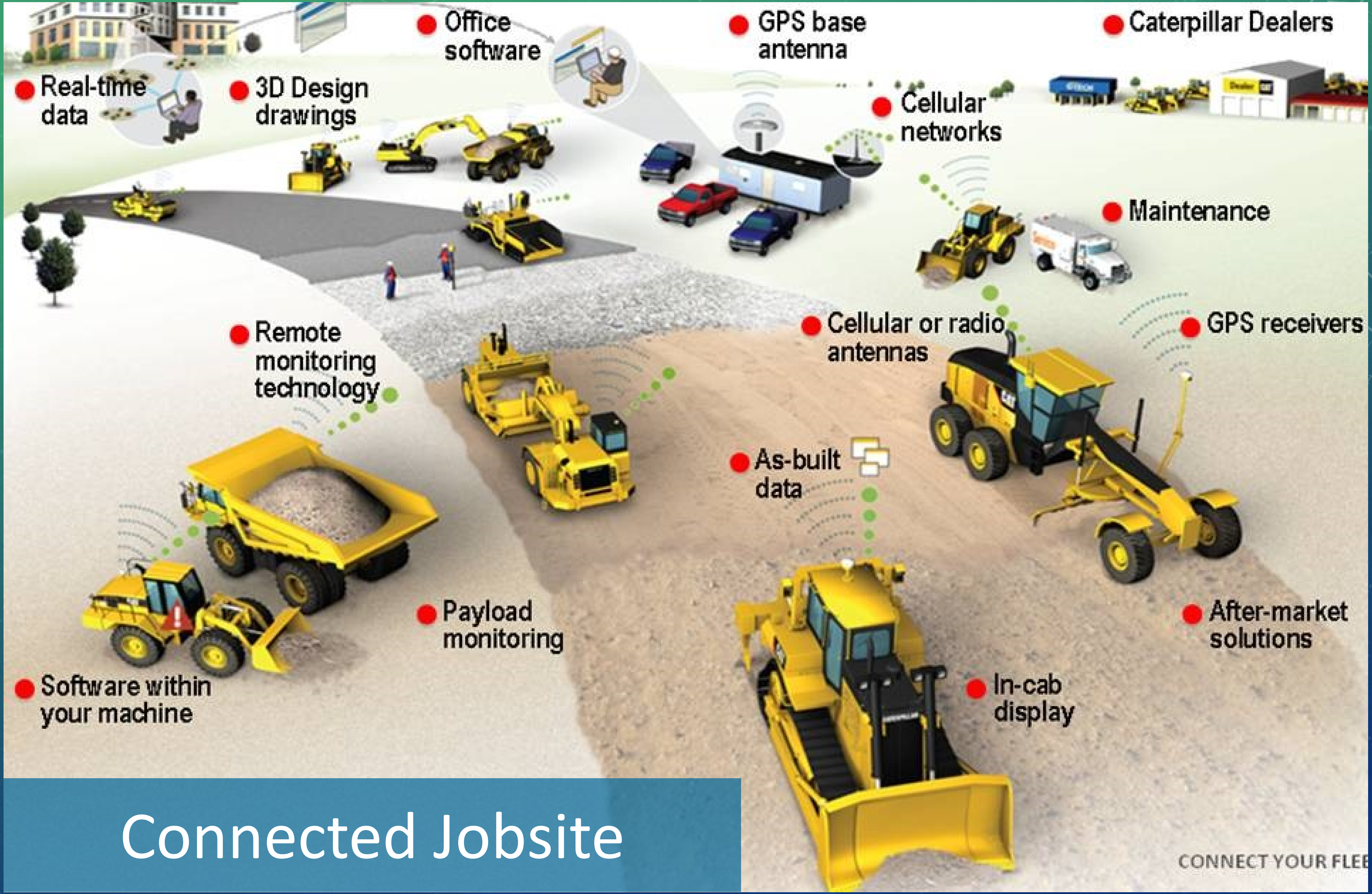
OUTLINES

- Definition of Intelligent Construction Technologies (ICT)
- FHWA ICT Efforts
- Key ICT – Benefits, Challenges and Solutions
- **ICT Integration**
- ICT Guidance
- Case Studies

CONSTRUCTION/DATA MANAGEMENT

- Construction Management
  - 3D Modeling
  - 4D Modeling (3D + work progress)
  - Project Visualization
- Automated Data Management
  - Link Field, Office and Material Suppliers

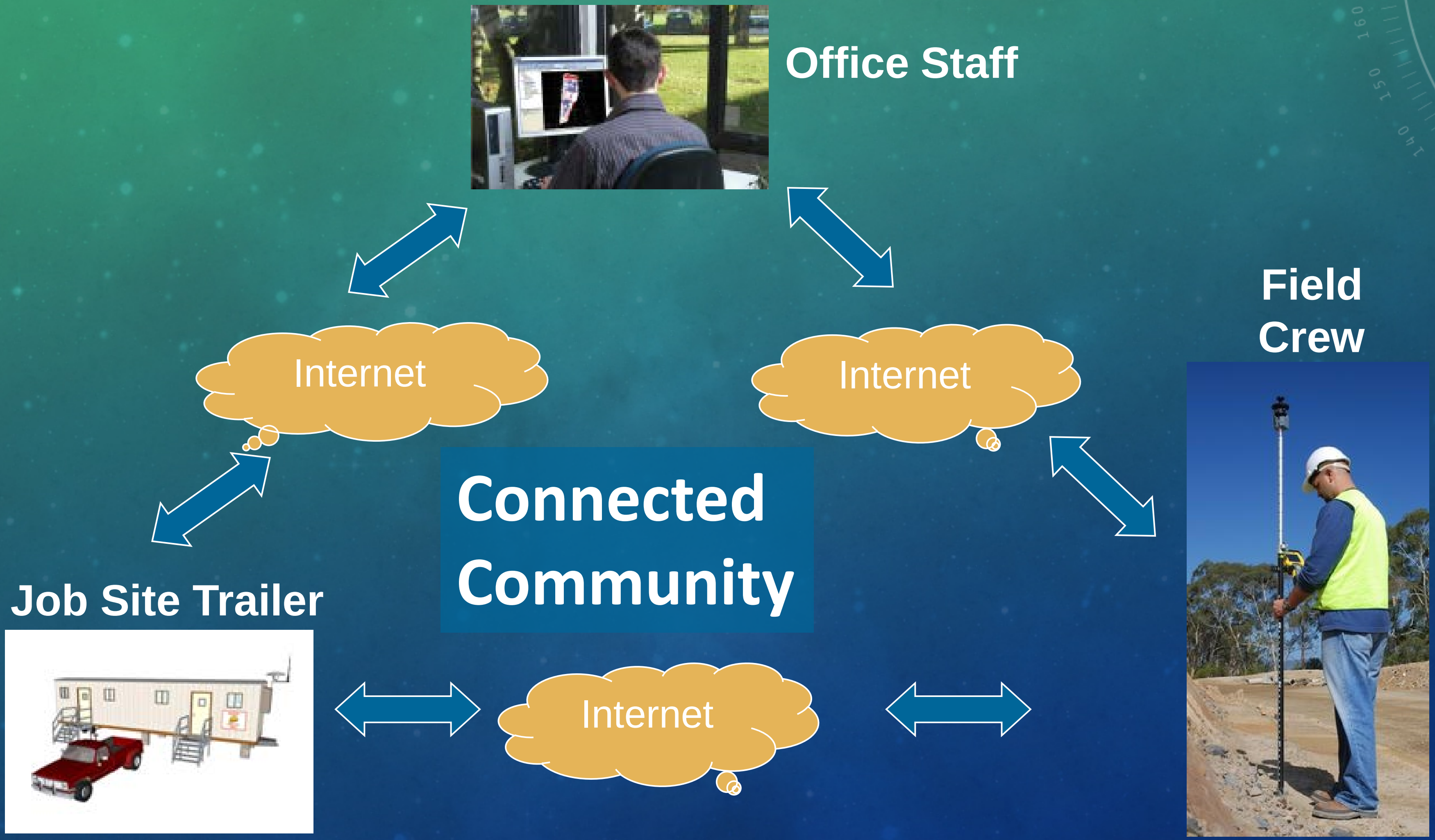
Connected Jobsite



Courtesy Caterpillar

Trimble

Connected via Cloud



Trimble

IICTG.org

DATA INTEGRATION FOR IC

IC/TP data

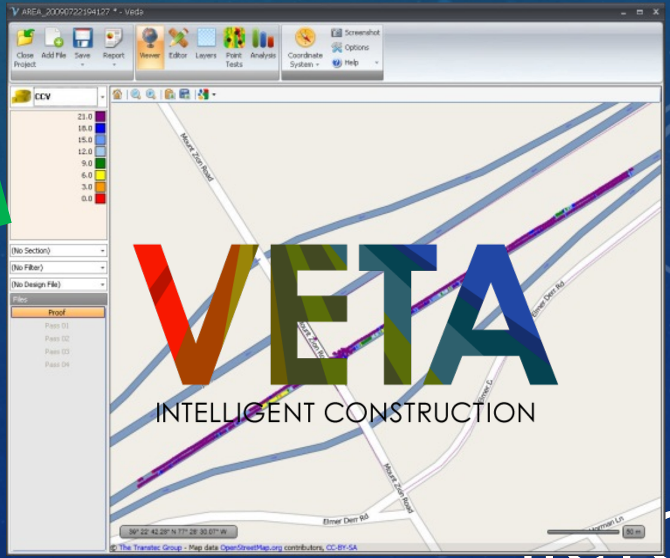
Man
US

Automatic
or Manual

Vendor's
cloud
Server

Dat Export
USB, email,
etc.

FTP/HTTP

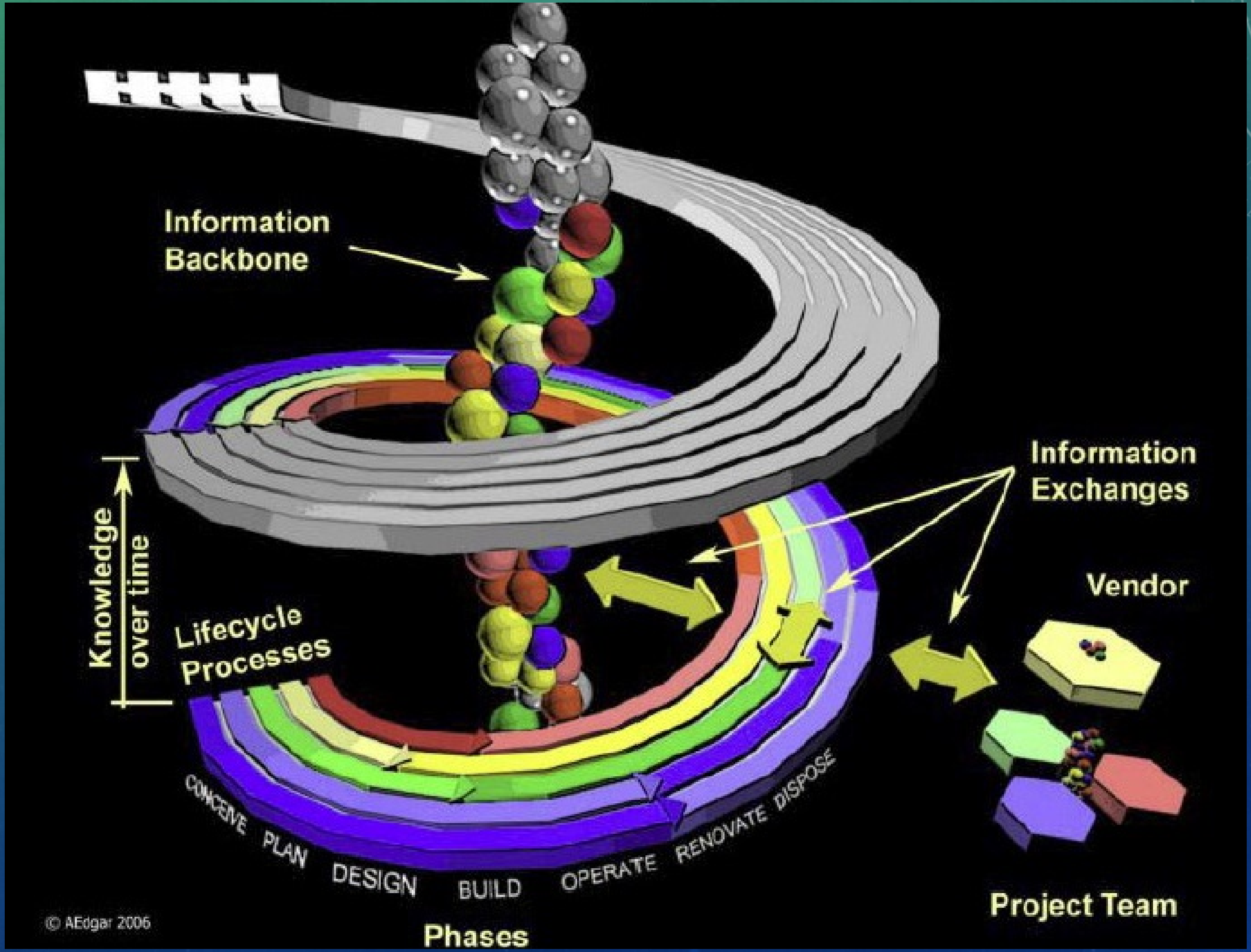


Spot test data

Manual

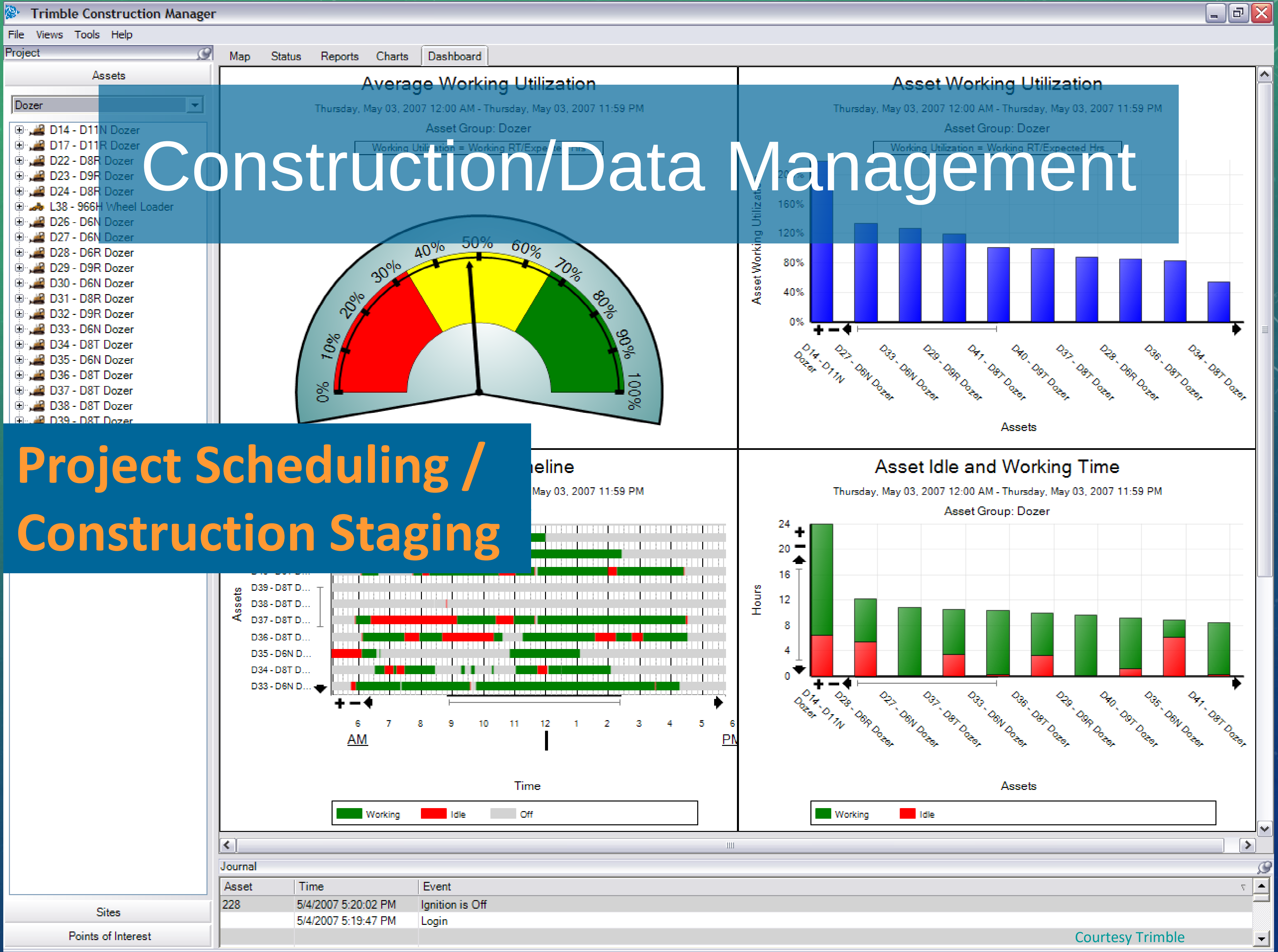
G.org

3D-CENTRIC INTEGRATION



IICTG.org

Construction/Data Management



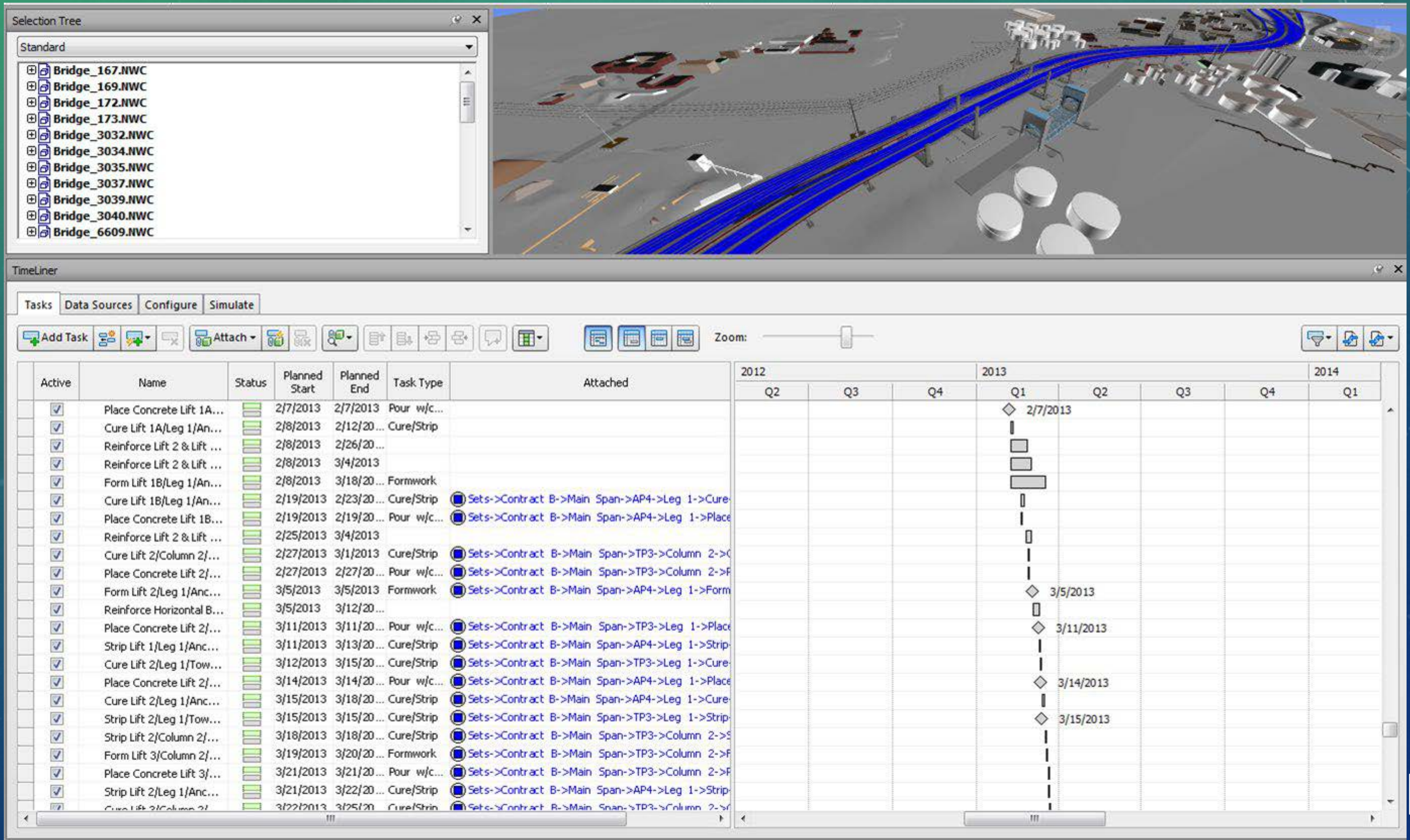
Project Scheduling / Construction Staging

Courtesy Trimble

ICTG.org

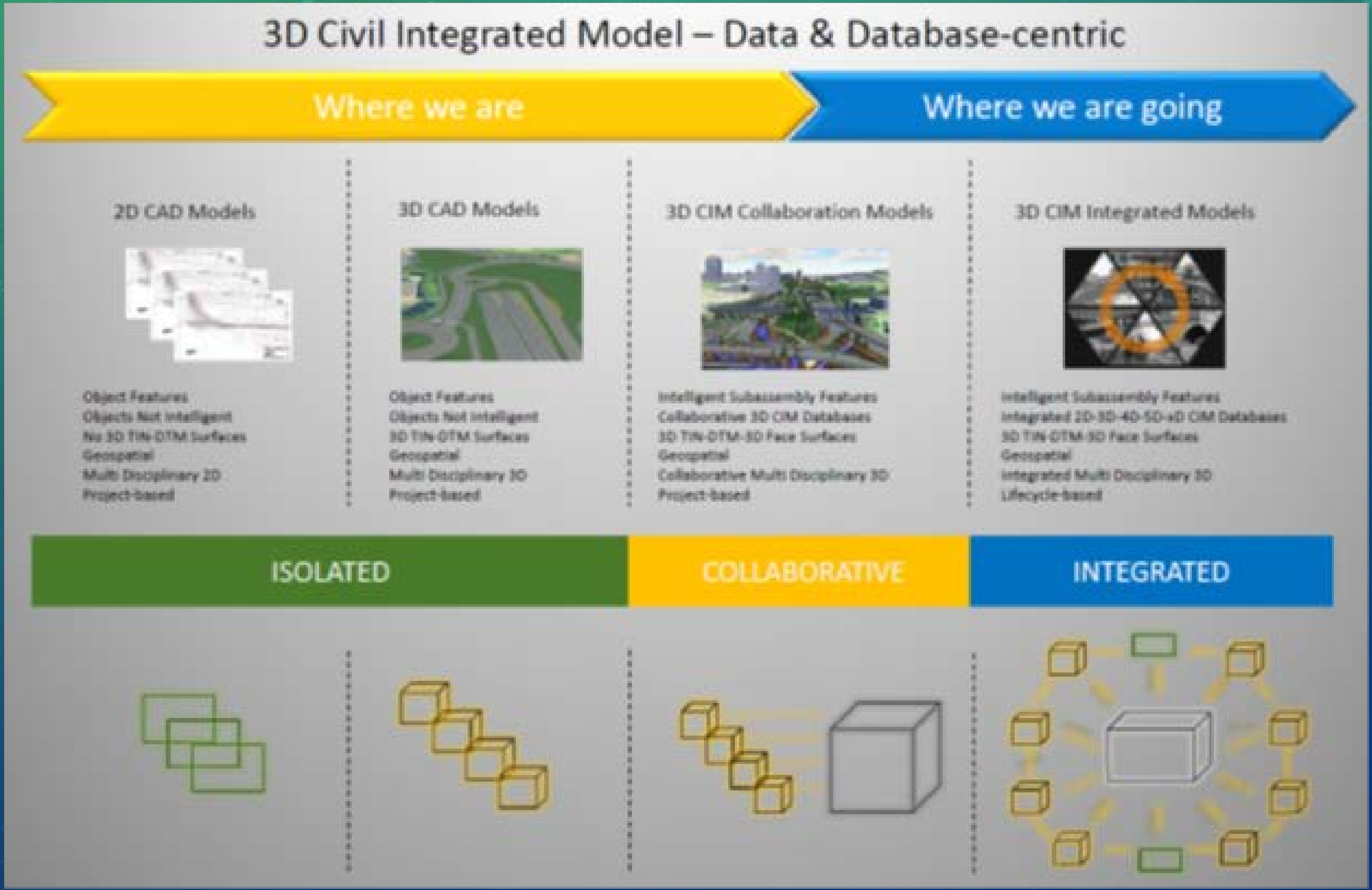
4D MODEL AND DATA MANAGEMENT

COTS software



ICTG.org

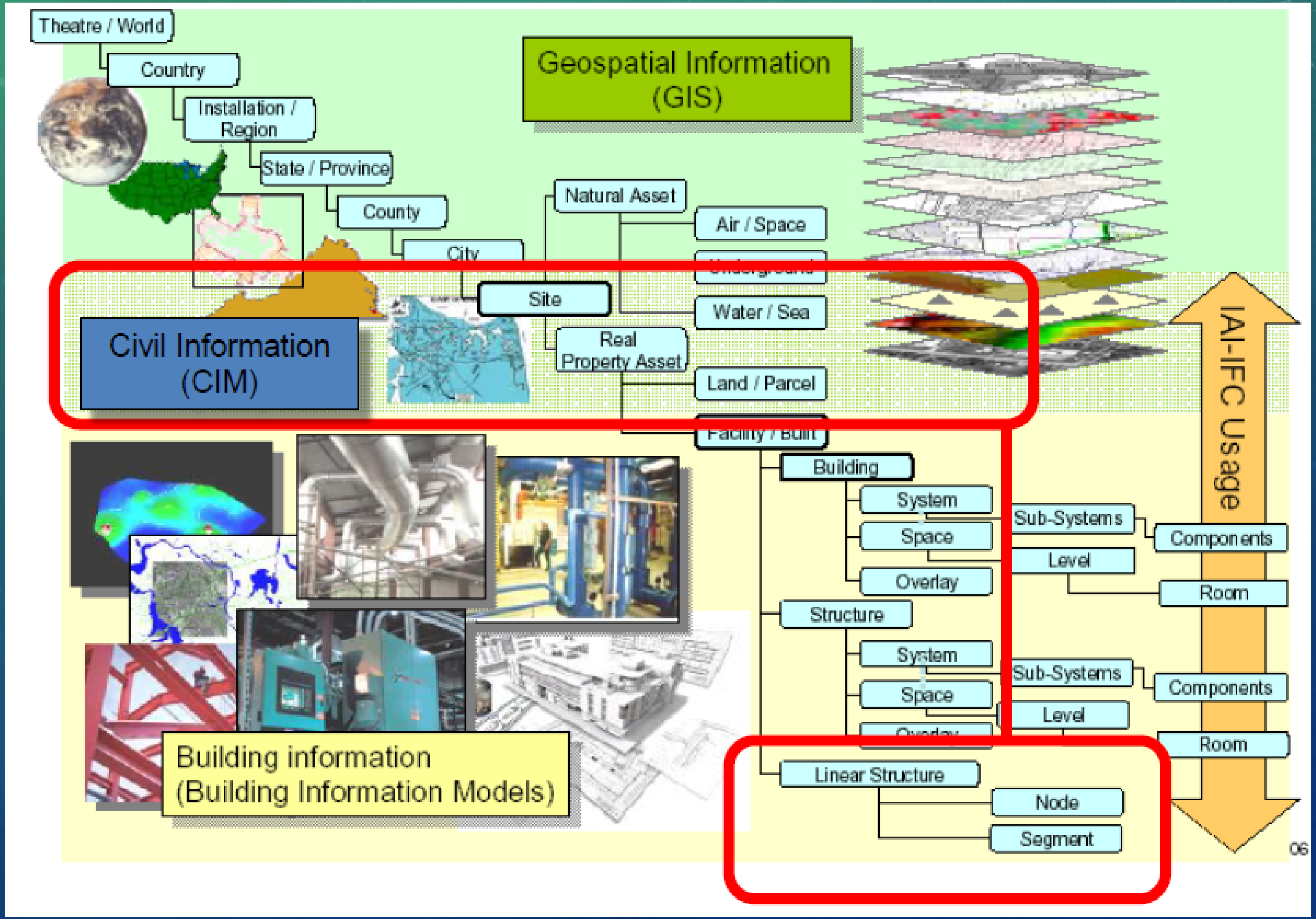
CIM - CIVIL INTEGRATED MANAGEMENT



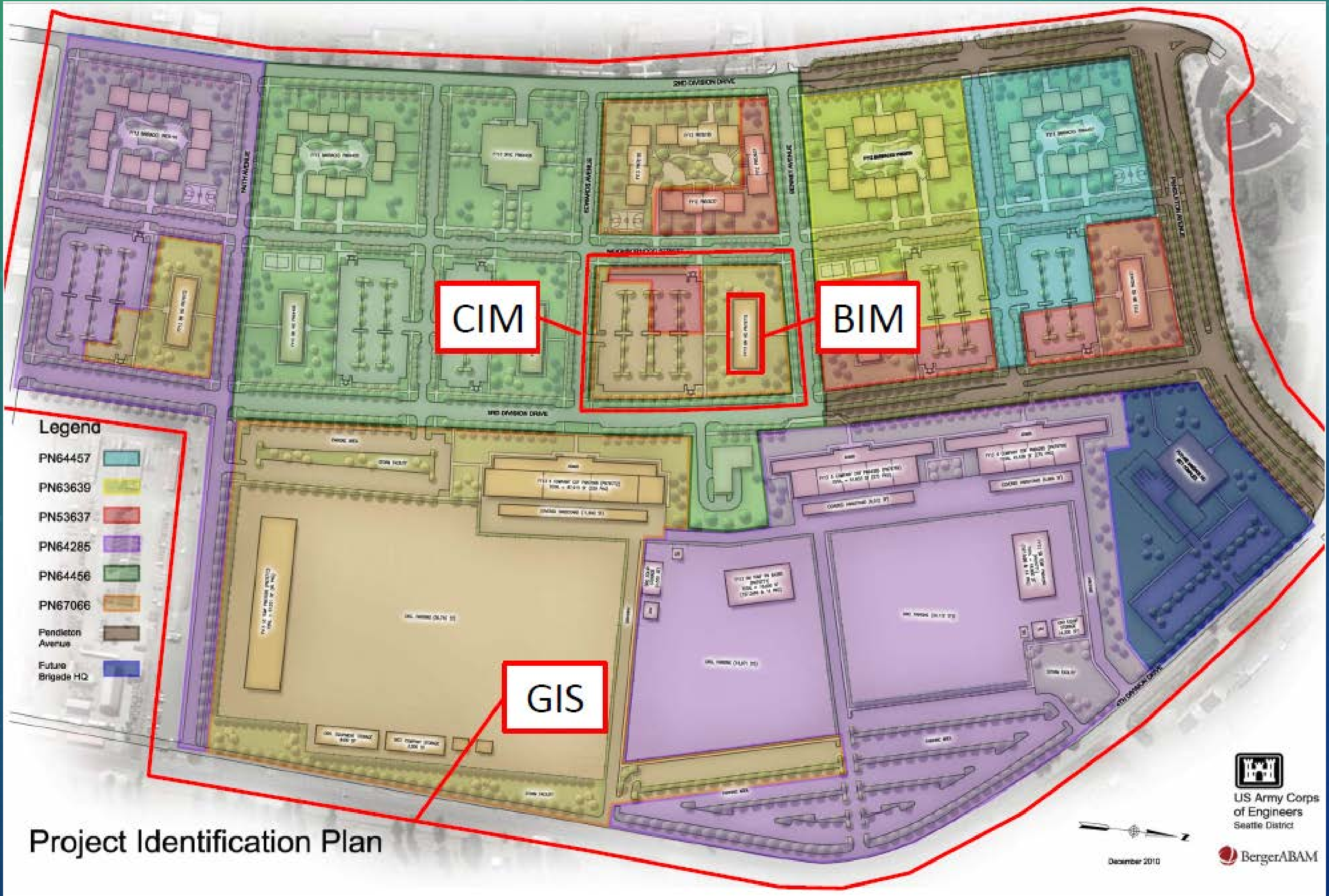
Parve, WisDOT 2014

IICTG.org

GIS – CIM - BIM


Theatre / World
Country
Installation / Region
State / Province
County
City
Site
Natural Asset
Air / Space
Water / Sea
Real Property Asset
Land / Parcel
Geospatial Information (GIS)
Civil Information (CIM)
Building
System
Space
Overlay
Sub-Systems
Components
Level
Room
Structure
System
Space
Sub-Systems
Components
Level
Room
Linear Structure
Node
Segment
IAI-IFC Usage
Building information (Building Information Models)

GIS – CIM - BIM



CIM
BIM
GIS
Legend
PN64457
PN63639
PN53637
PN64285
PN64456
PN67066
Pendleton Avenue
Future Brigade HQ
Project Identification Plan
US Army Corps of Engineers
Seattle District
BergerABAM

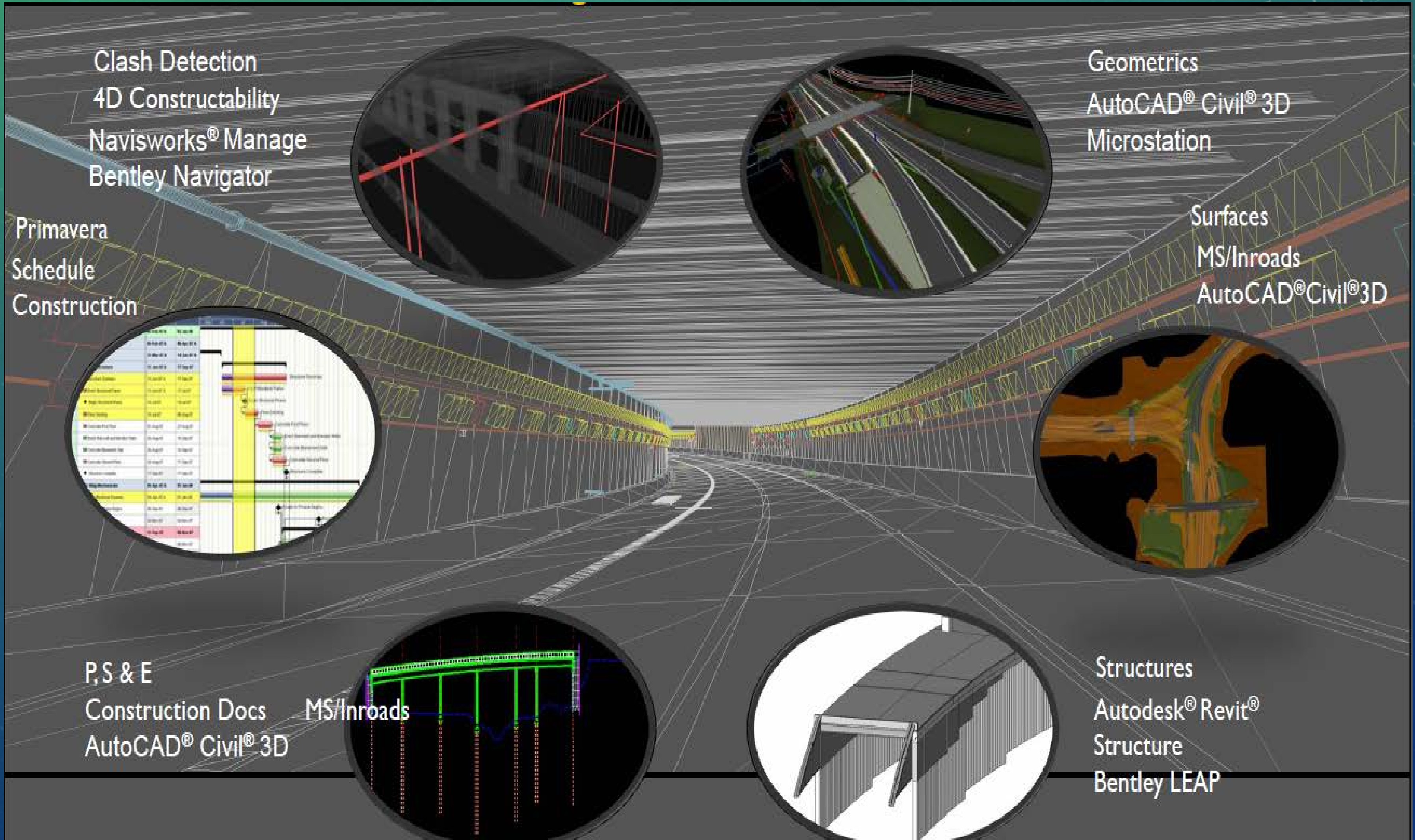
CIM-VDC PROCESS

VDC (Virtual Design and Construction)

- The databases, tools & processes use multidisciplinary performance models of design & construction input such as:
  - Building or Civil Information Models (3D),
  - CPM Schedules (4D),
  - Cost Estimates (5D) and
  - Specifications (6D)

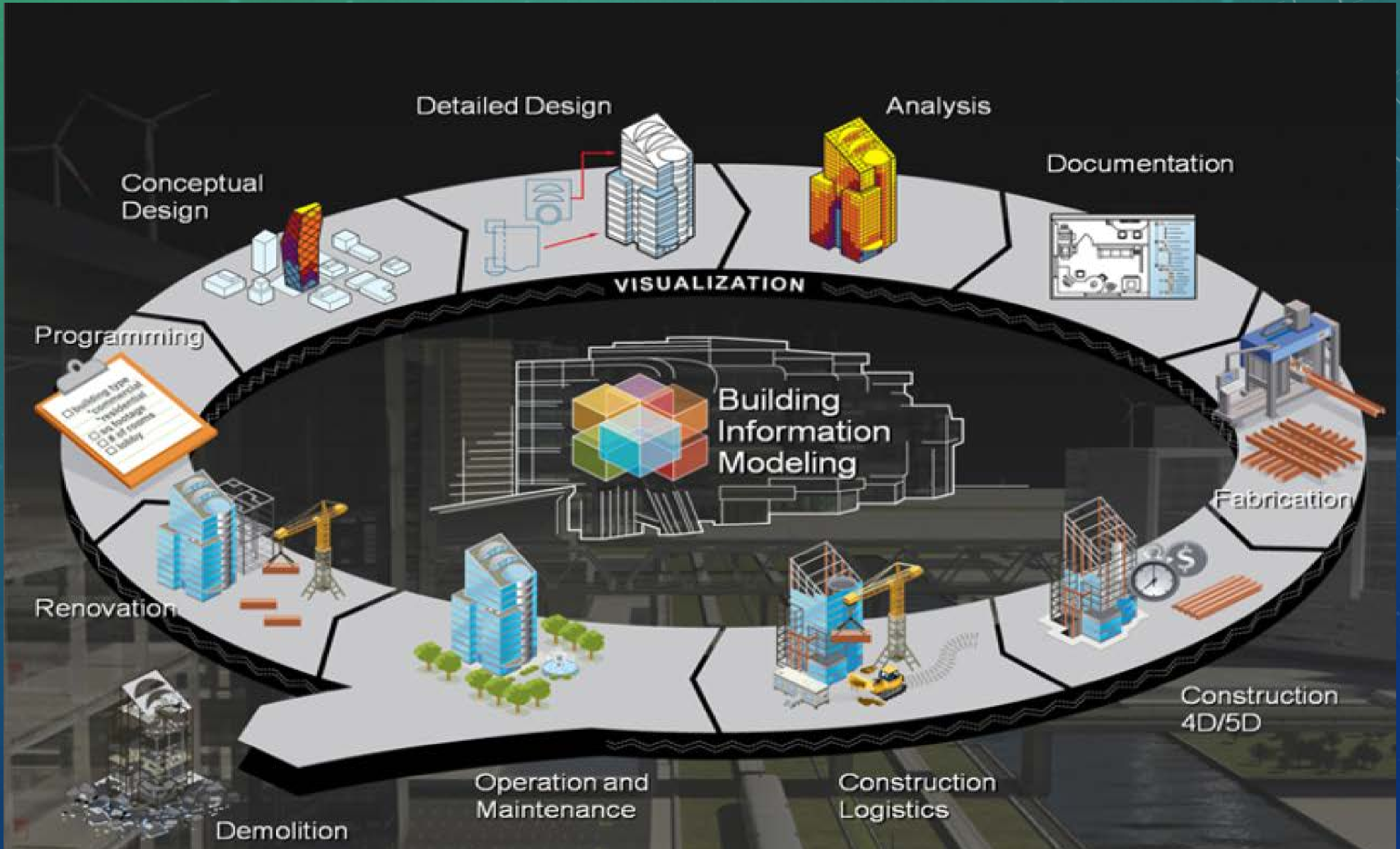
to simulate & validate project objectives.

INTEGRATION OF SOFTWARE TOOLS & PROCESSES



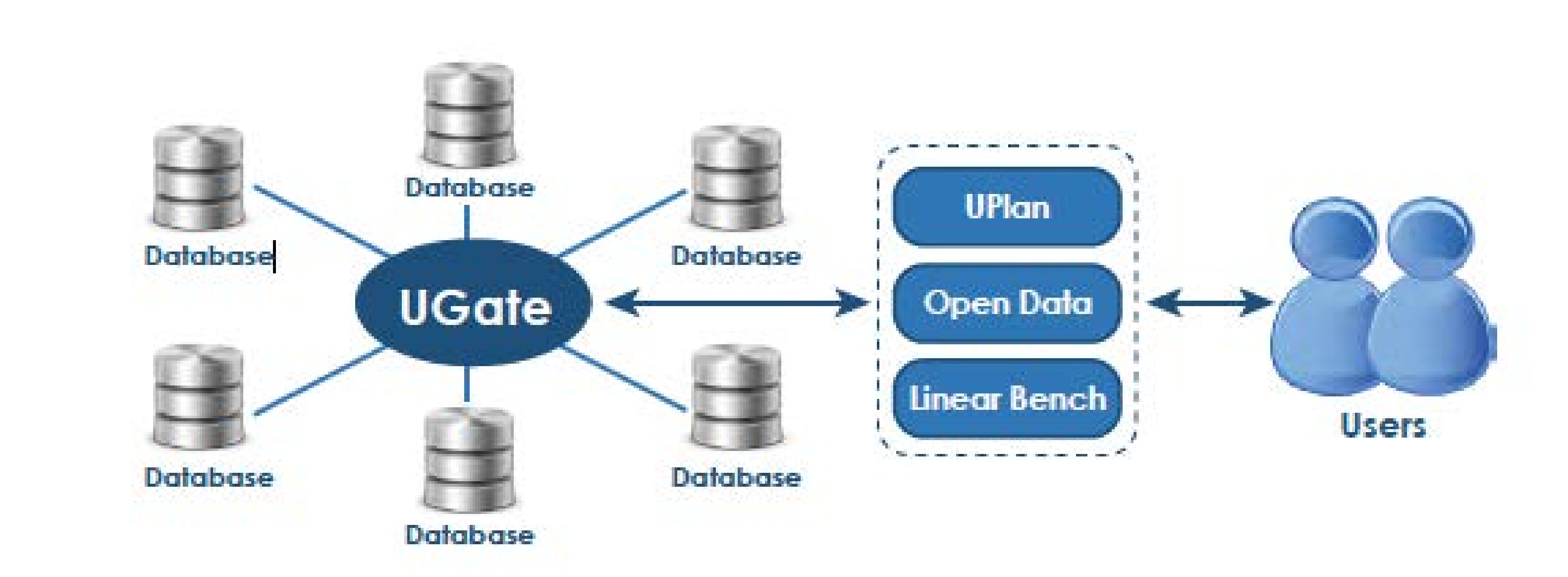
ICTG.org

BIM-VDC LIFE CYCLE



ICTG.org

EFFICIENT ASSET MANAGEMENT



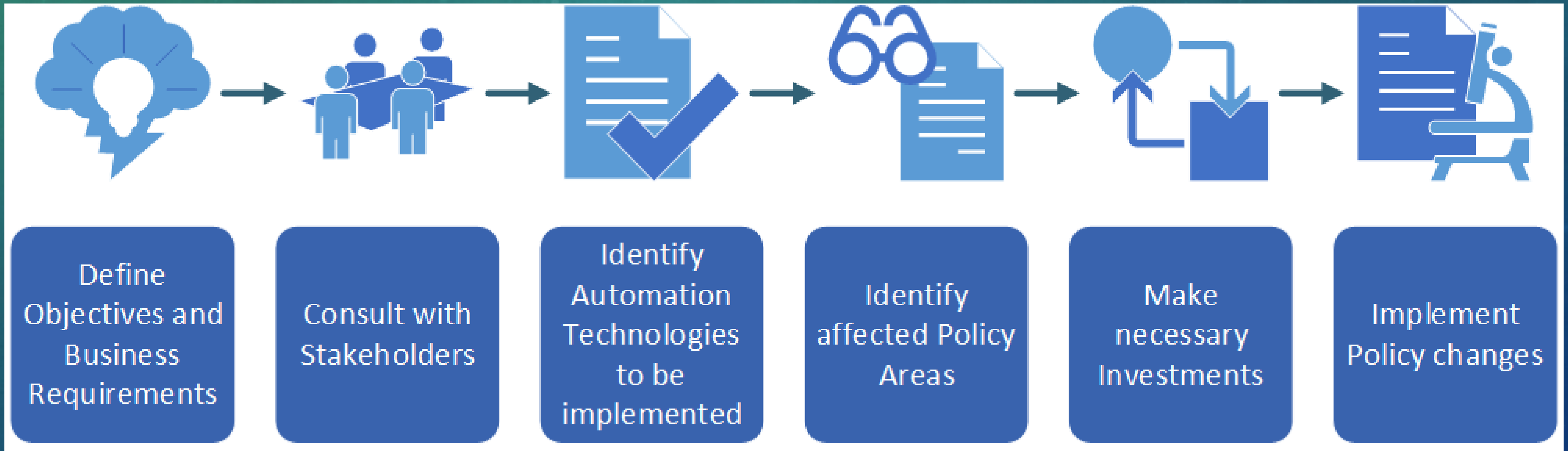
BENEFITS OF EFFICIENT ASSET MANAGEMENT

Use Case	Prior Time and Cost	New Time and Cost	Labor-Only Savings	Non-Quantifiable Benefits
Create project summary sheets for pavement preservation and rehabilitation projects (75 projects)	6 days/pr. $180,000	1.5 days/pr. $45,000	$135,000	Fewer change orders and more accurate estimates
Develop preliminary project estimates (30 Concept Reports)	100 hours $150,000	10 hours $15,000	$135,000	More accurate estimates, better responsiveness to public due to faster reporting
Identify safety improvements that can be made with projects (40 Operational Safety Reports)	$7,500/proj. $300,000	$2,500/proj. $100,000	$200,000	Higher quality analysis with more recommendation options, able to perform analysis quickly in programming and scoping phase
Assess safety elements and crash conditions using usRAP and BYU Safety Modeling (5,000 miles)	0.5 hr./mile $125,000	40 hours $2,000	$100,000	N/A

OUTLINES

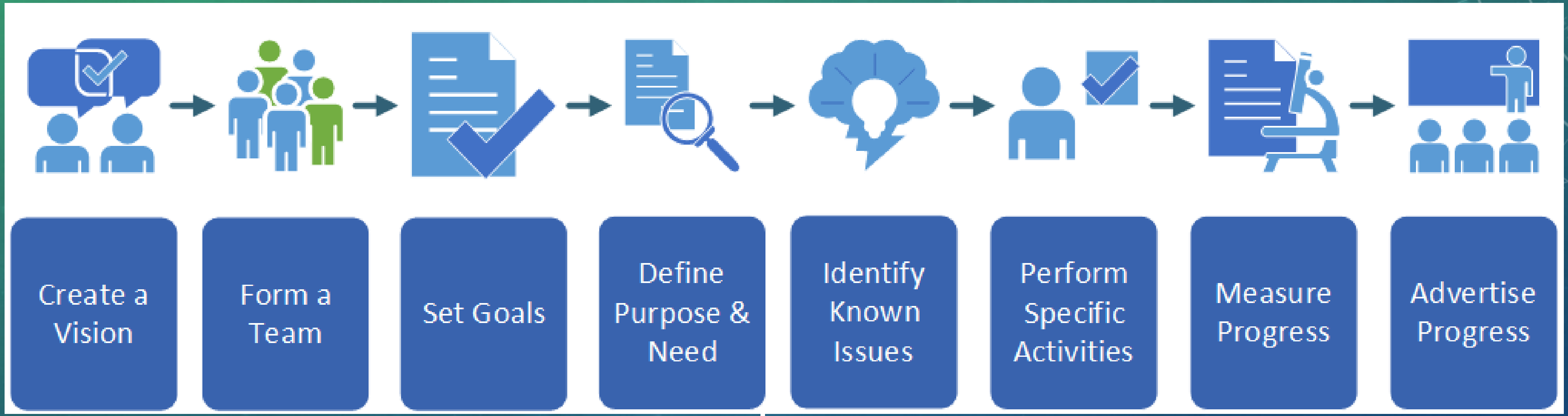
- Definition of Intelligent Construction Technologies (ICT)
- FHWA ICT Efforts
- Key ICT – Benefits, Challenges and Solutions
- ICT Integration
- **ICT Guidance**
- Case Studies

DEVELOPMENT OF AUTOMATION TECHNOLOGY POLICY



.....involve with many stakeholders and partners in construction

IMPLEMENTING
AUTOMATION TECHNOLOGY



Initiative	Status	Task No.	Description	Start Date	End Date	Sponsor	Committee Chair	Initiative 2 Leader	Initiative 3 Leader	Stakeholder Group 1	Stakeholder Group 2
Initiative 1		*1*	*Coordination*	*1/1/15*	*ongoing*						
Coordination		1.1	Form an Implementation Team	1/1/15	2/28/15	C	A	R	R	C	C
Coordination		1.2	Hold quarterly team meetings	3/1/15	ongoing	I	A	R	R	R	R

Sample Resource Assignment Matrix (RAM)

IICTG.org

RAPID DEPLOYMENT

a small team with decision-making power

executive sponsor/manage the implementation

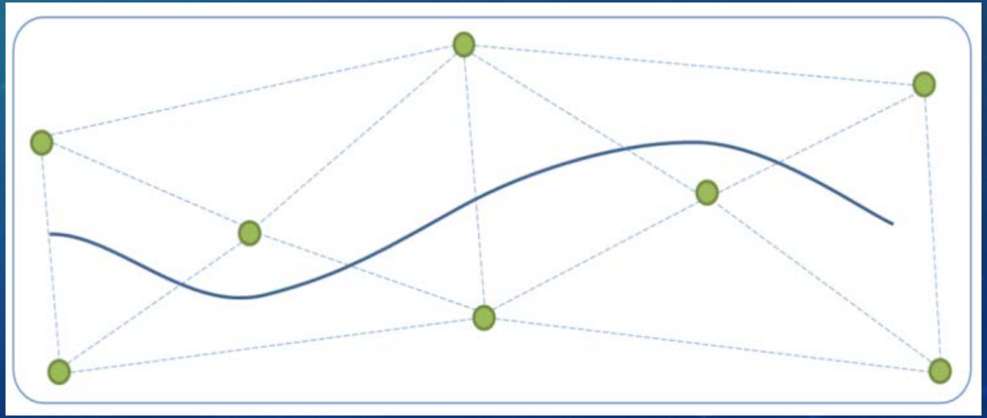
ENABLING INFRASTRUCTURE FOR AUTOMATION TECHNOLOGY

Enabling Infrastructure	1 Initial	2 Evolving	3 Defined
Statewide CORS Network	Limited access to a CORS network	Statewide CORS network that is asset/GIS-grade only	Limited access to survey-grade CORS network
Real Time GNSS Network (RTN)	Single Base RTK, requires site localization	Commercial RTN solution, requires site localization	Commercial RTN solution, tied to the NSRS
Coordinate Reference System	State Plane coordinate system used on all projects	Modified State Plane coordinate system used on all projects	Some projects use custom coordinate systems
Computer Hardware for Design	All staff have computers	All staff have networked computers	All staff have networked computers that are less than 3 years old
Computer Software for Design	Email, Internet, PDF and Office software only	CADD design software for designers and technicians	CADD design software for all and limited access to design review software
CADD Standard	CADD Manual documents minimum requirements for 2D electronic plans	CADD Manual outlines minimum requirements for 3D model used to generate 2D plans	Standardized 3D model format and outputs including standard file naming convention

Capability/Maturity Matrix for Enabling Infrastructure

GUIDELINES
SETTING CONTROL

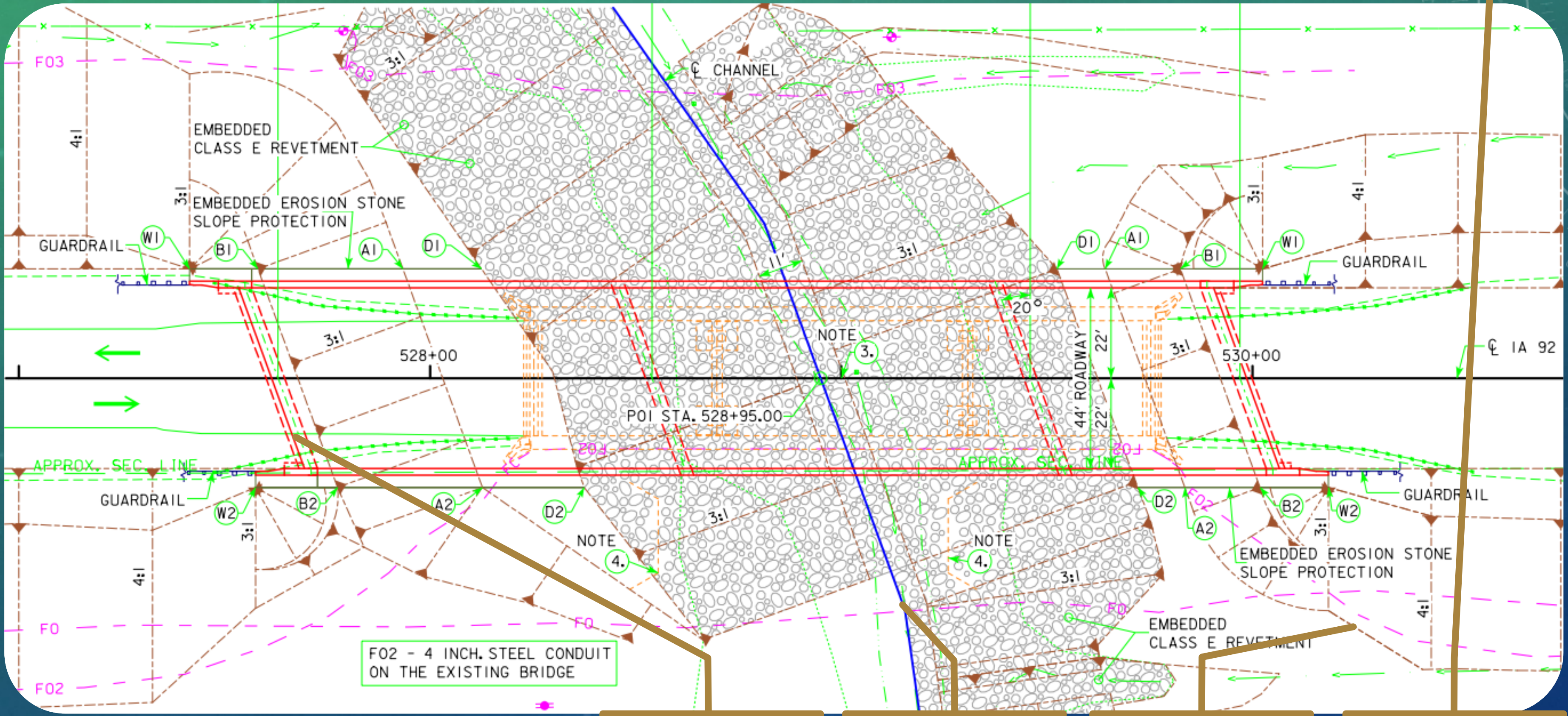
Control Type	Network Accuracy
Horizontal Control	0.10 ft
Vertical Control	0.02 ft



Alignment Control

GUIDELINES

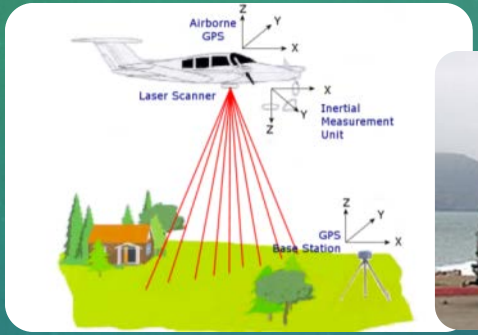
TOPOGRAPHIC SURVEY ACCURACIES

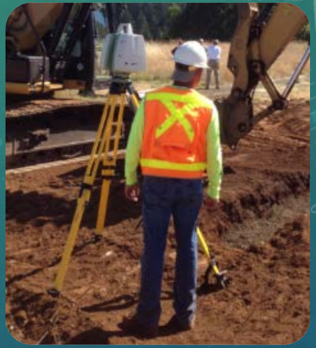


Constraint Feature	Design Feature	Location Feature	Planning Feature
H +/- 0.04 ft	H +/- 0.1 ft	H +/- 0.25 ft	H +/- 0.5 ft
V +/- 0.02 ft	V +/- 0.04 ft	V +/- 0.1 ft	V +/- 0.5 ft
5-ft spacing	10-ft spacing	25-ft spacing	50-ft spacing

IICTG.org

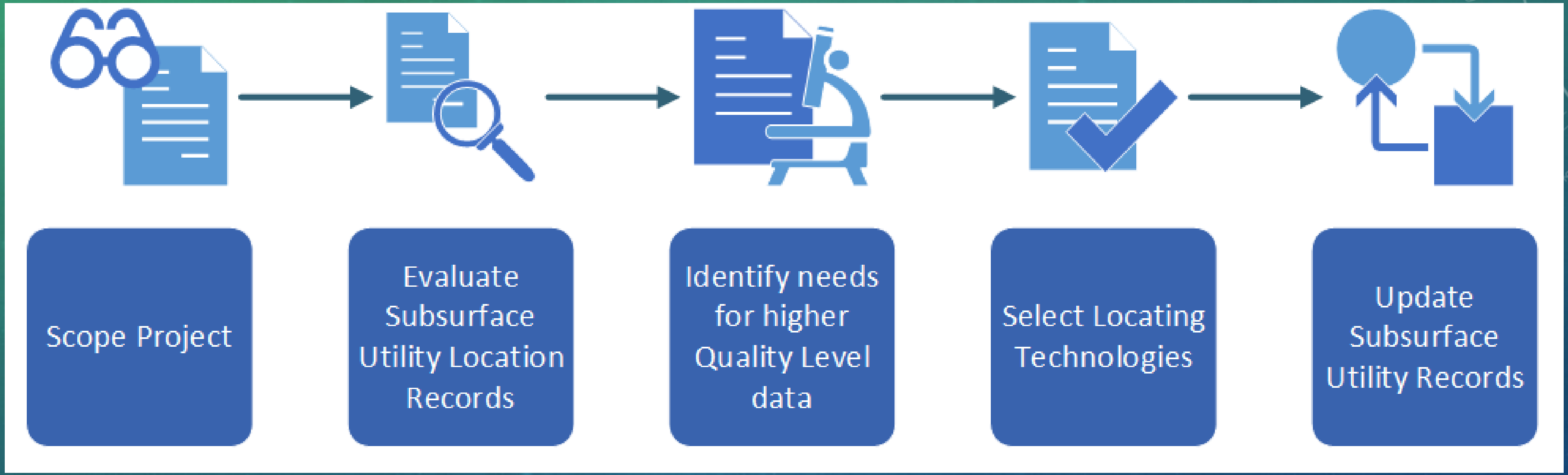
GUIDELINES
REMOTE SENSING

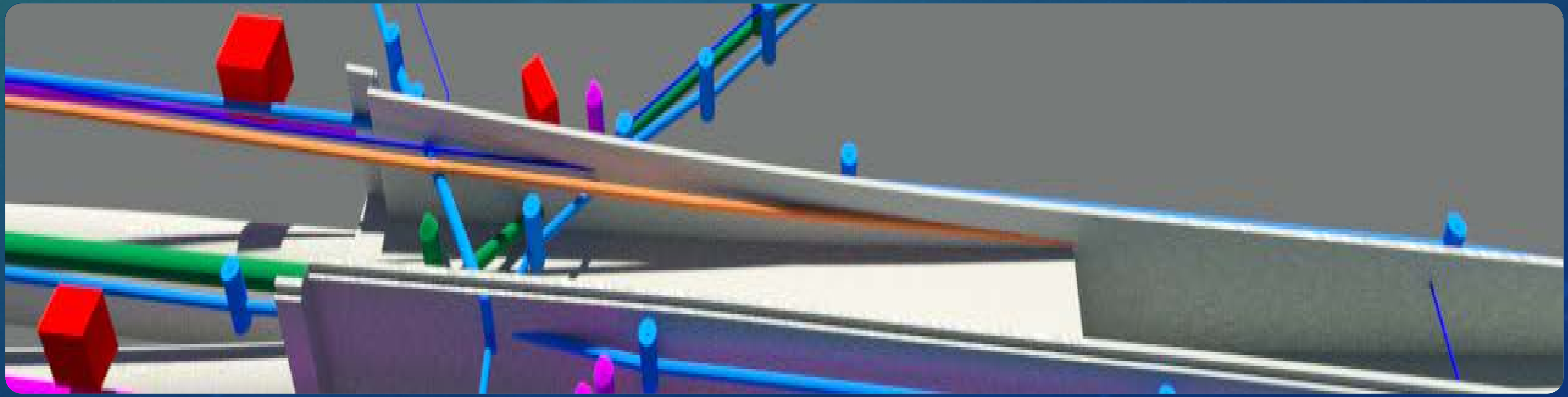




Feature Type	Aerial LiDAR	Mobile LiDAR	Static LiDAR
Constraint Features	not appropriate	not appropriate	suitable
Design Features	not appropriate	consider	suitable
Location Features	consider	suitable	consider
Planning Features	suitable	suitable	consider

GUIDELINES
SUBSURFACE UTILITY LOCATION

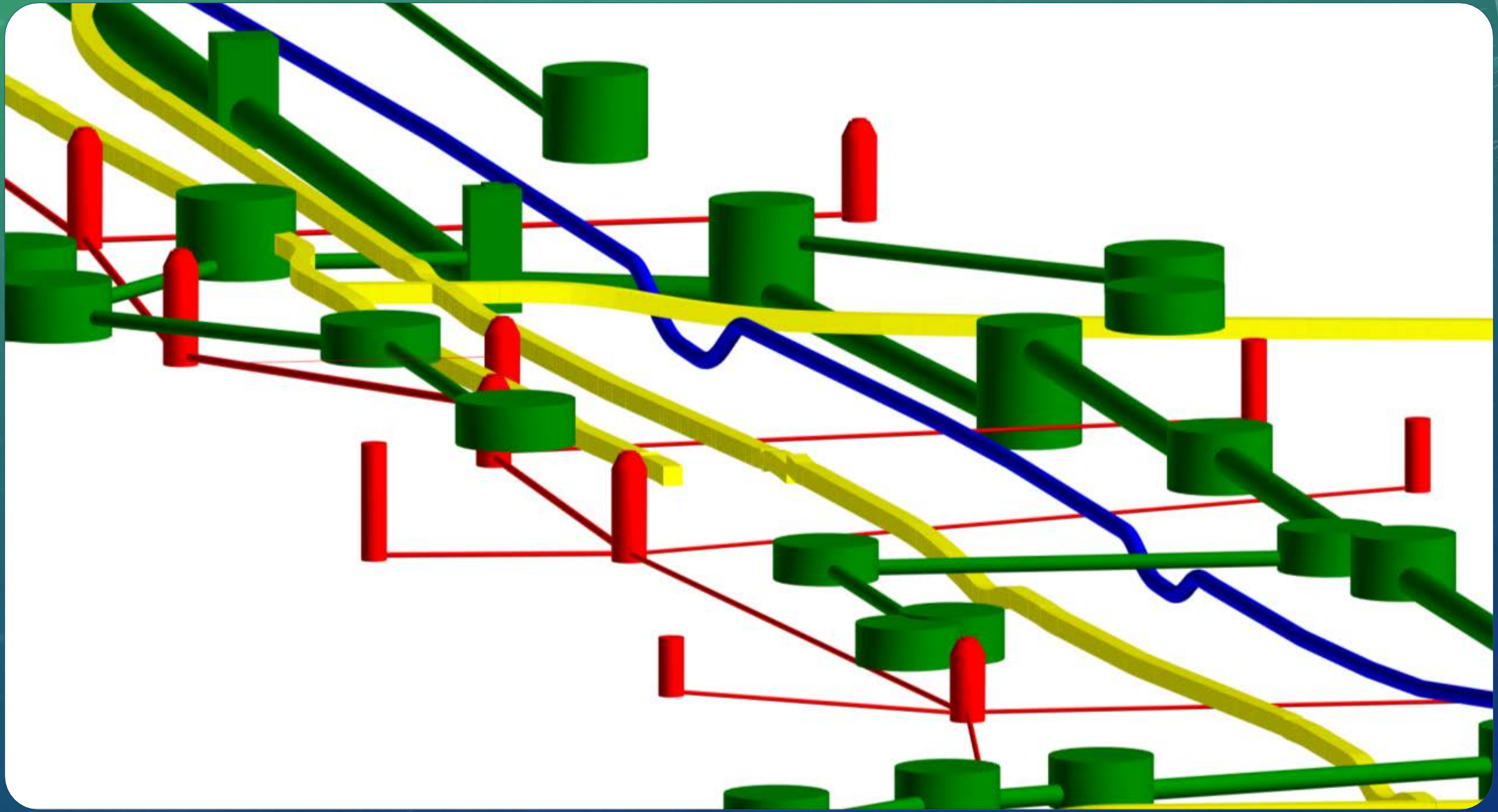




tunnel portal

GUIDELINES

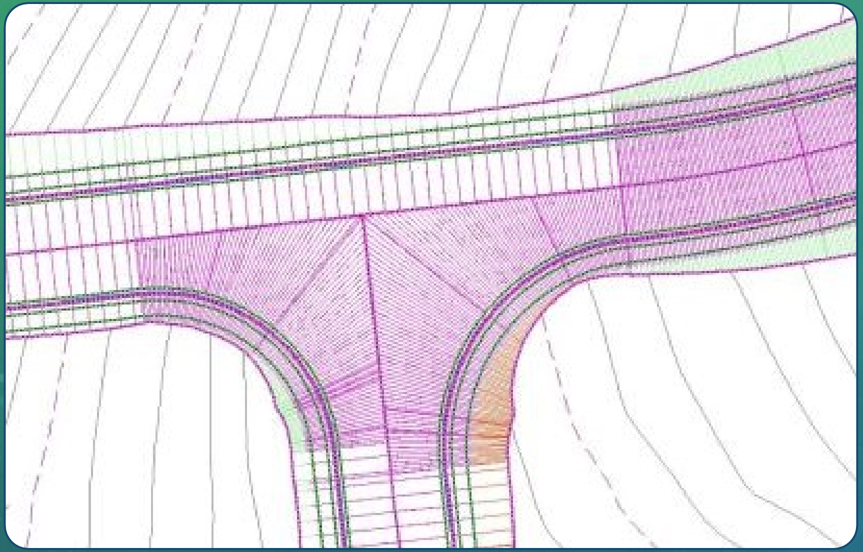
SUBSURFACE UTILITY DATA MANAGEMENT

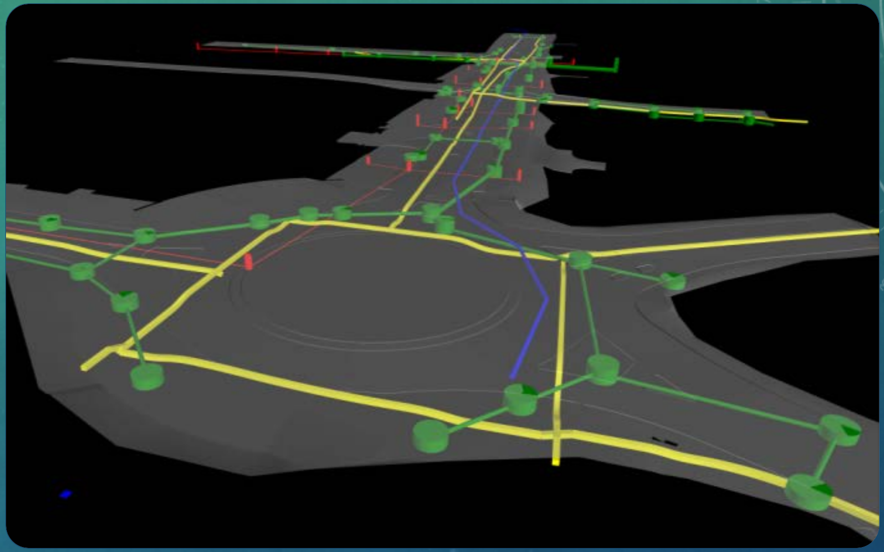


Use color and levels to distinguish between the different quality levels of subsurface utility data.

GUIDELINES

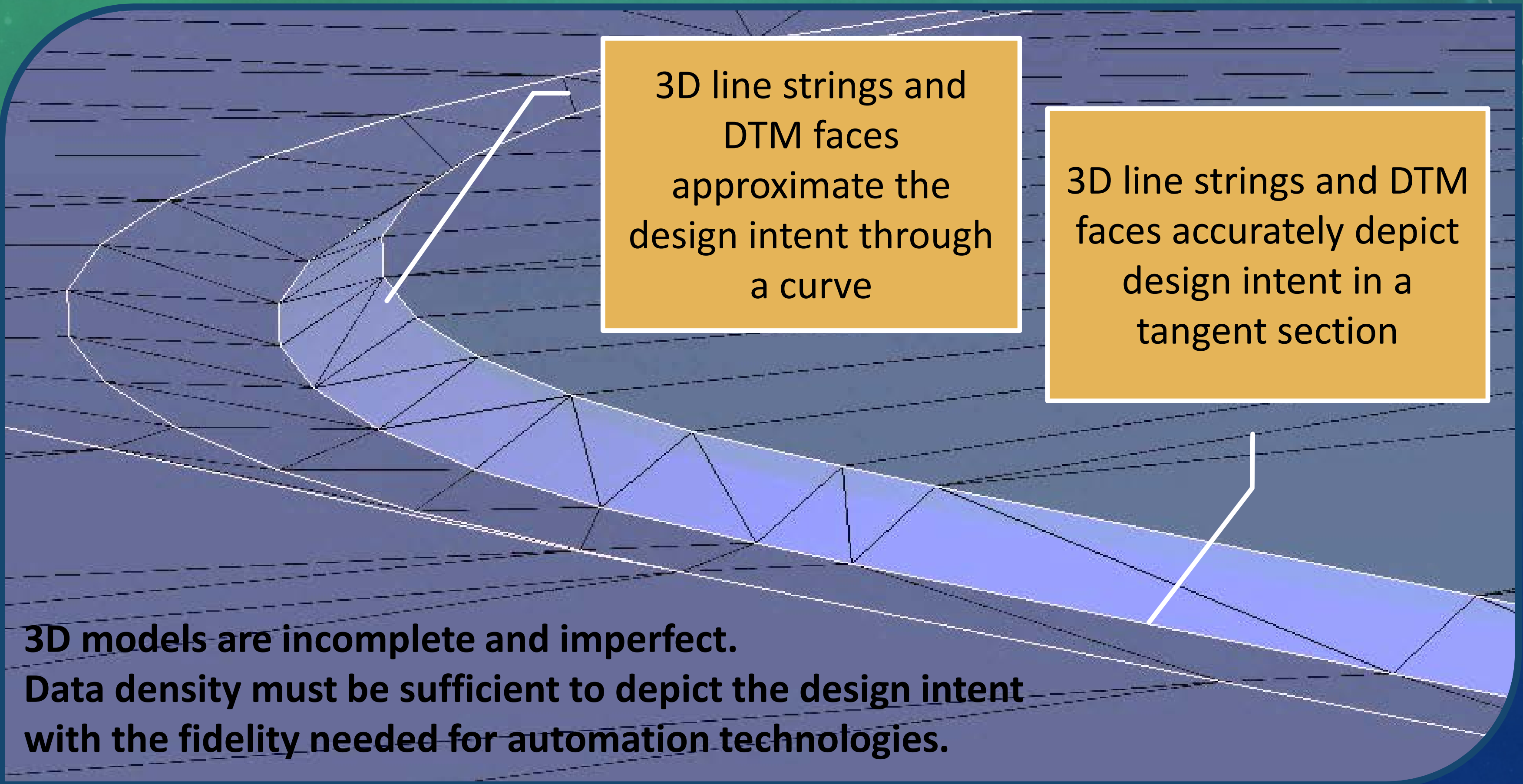
3D MODEL STANDARD - CONTENT





CADD Data Type for Automation	Features
alignment, surface & 3D line strings	Roadways, interchanges, intersections
surface & 3D line strings	Side slopes, gore areas, sidewalks and paths, lane width transitions, culvert headwall grading, guardrail berm transitions, benching transitions, bridge abutments, storm water ponds, ditches and swales
3D line strings	Pavement markings, curbs and gutters, retaining walls, sewer inverts

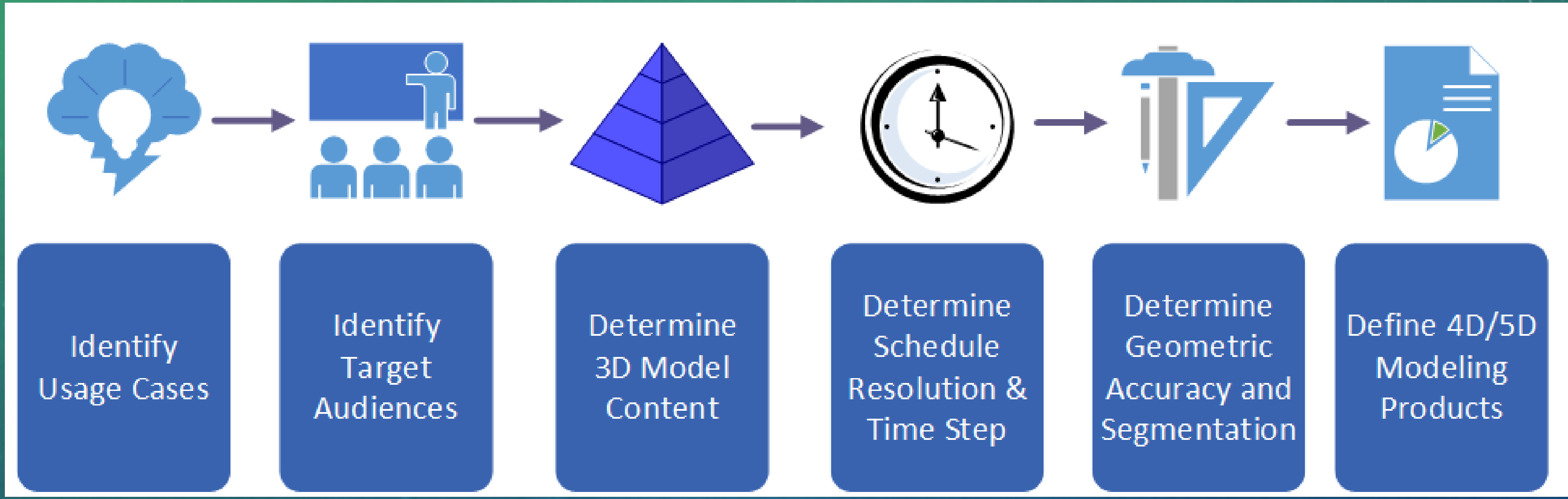
GUIDELINES
3D MODEL STANDARD - DENSITY

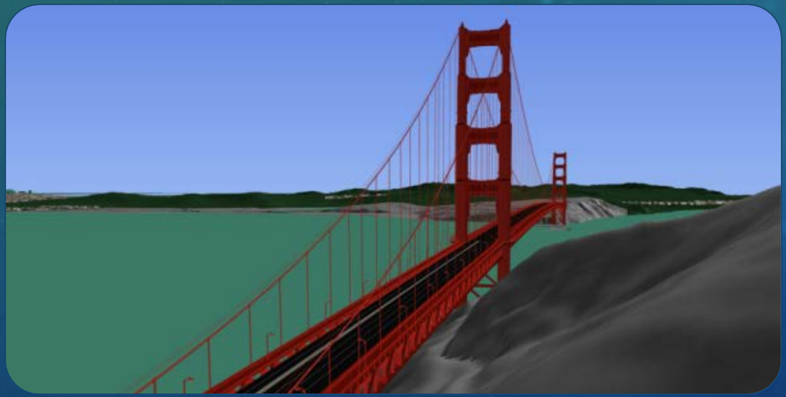


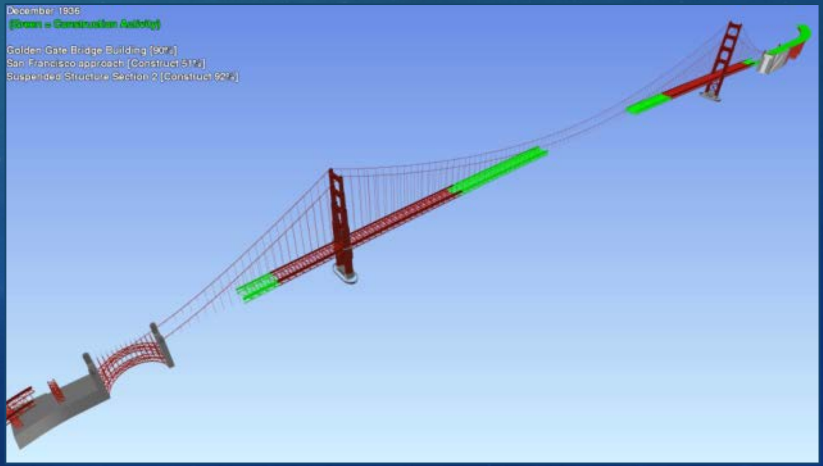
3D models are incomplete and imperfect.
Data density must be sufficient to depict the design intent with the fidelity needed for automation technologies.

GUIDELINES

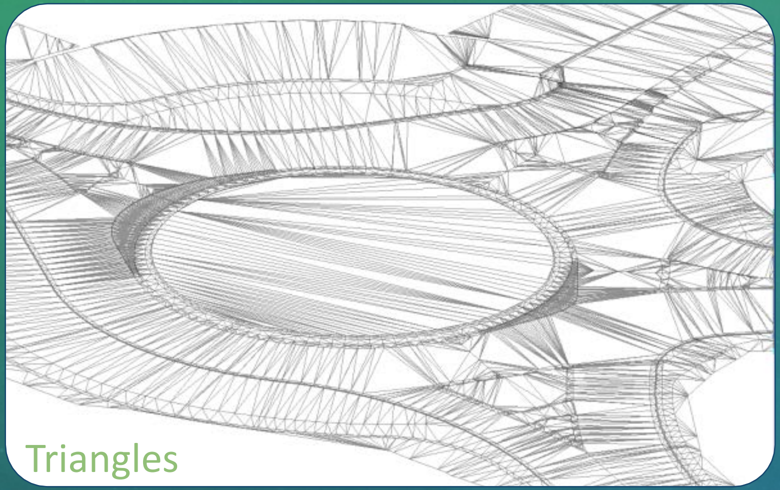
4D MODEL STANDARD

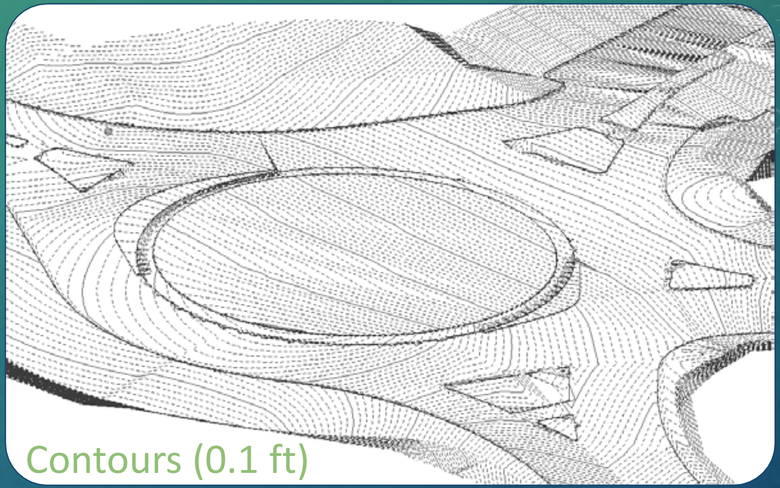


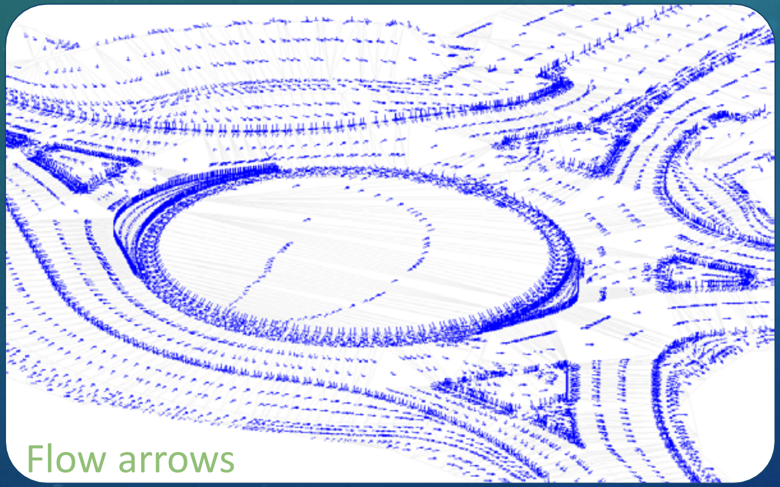


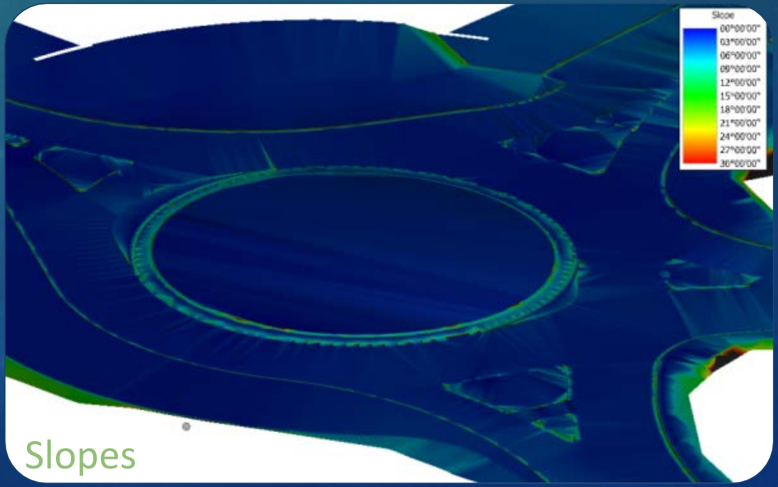


GUIDELINES
3D MODEL REVIEWS


Triangles


Contours (0.1 ft)


Flow arrows

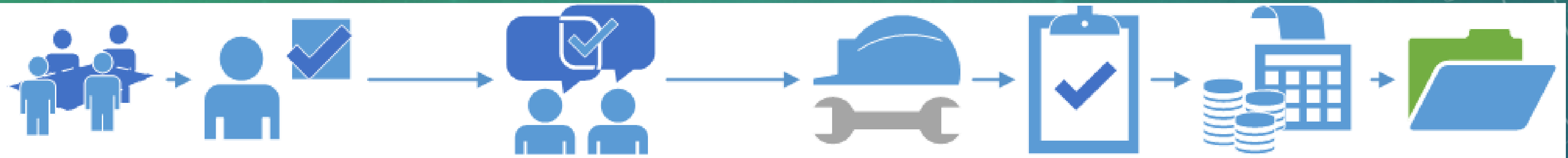

Slopes

GUIDELINE SPECIFICATIONS
MANAGING CONSTRUCTION AUTOMATION

Section of Standard Specifications	Considerations to Support use of automation technologies
Controlling Work: Plans and Working Drawings	Owner's provision of 3D data, Review and agreement of electronic plan data, including 3D digital data, Requirements for 4D/5D models, Provision of as-built records
Controlling Work: Conformance with Plans and Specifications	Standing of 3D data in relation to other contract documents
Controlling Work: Construction Stakes, Lines and Grades	Verifying control position, accuracy and usage, Agreeing a site localization, Staking requirements
Controlling Work: Inspection of Work	Provision of equipment for performing inspection, Requirements for notification of work ready to inspect
Controlling Work: Quality Control Plan	Use of a Work Plan to agree use of automation technology in construction and inspection, including minimum requirements for equipment calibration.
Measurement and Payment	Means of measurement and payment
Earthwork, Base Material, Fine Grading, Asphalt Paving, Concrete Paving	Accuracies, tolerances, means of measurement and payment

GUIDELINES

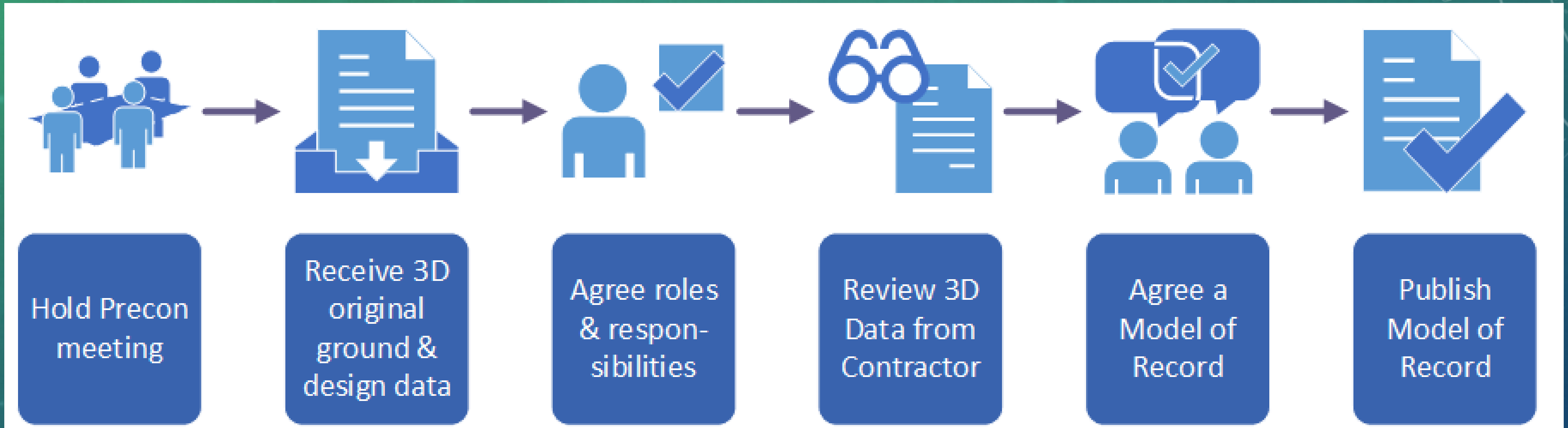
FIELD TECHNOLOGY & INSPECTION



Hold Precon meeting → Agree roles & respon-sibilities → Develop plans for digital data management, low accuracy positioning and high accuracy positioning → Select tools → Inspect work → Document quantities and tolerances → Store digital as-built records

GUIDELINES

ESTABLISHING A MODEL OF RECORD

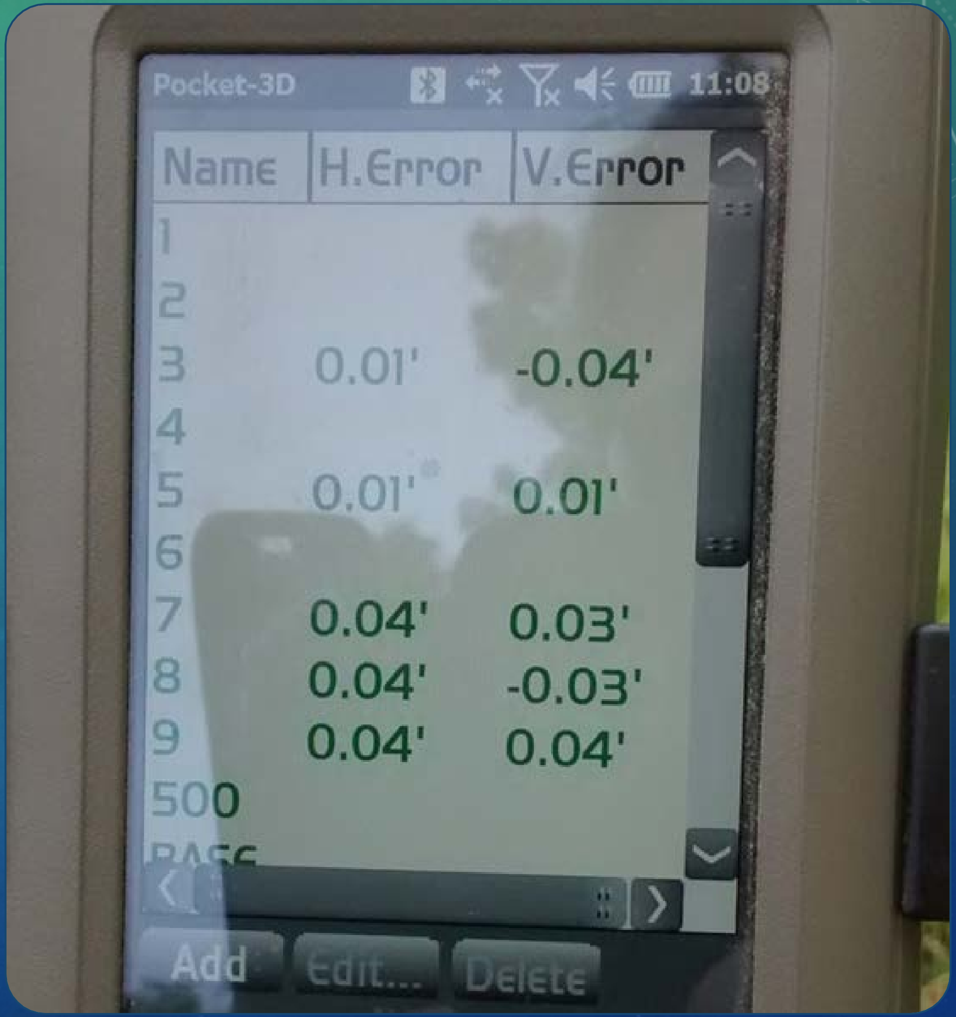


Name	Size	Date
\81-1961-021_E_Files_(DataFiles)\Alignment_Data_Files		
hv_dsn_021.xml	275.4 KB	12/12/2014 11:17
\81-1961-021_E_Files_(DataFiles)\Machine_Control_Surfaces		
existing_surface_021.xml	21.7 MB	12/12/2014 11:27
existing_surface_Stage2.xml	129.3 MB	12/12/2014 11:27
prop_surf_subgrade_completeA.xml	58.4 MB	12/12/2014 11:28

GUIDELINES

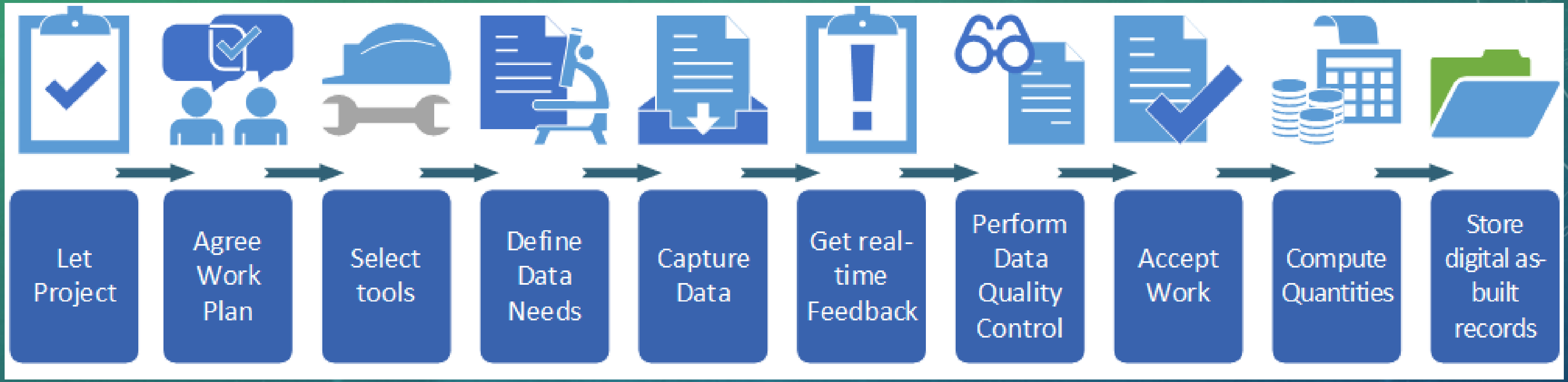
AGREEING CONTROL & SITE LOCALIZATION

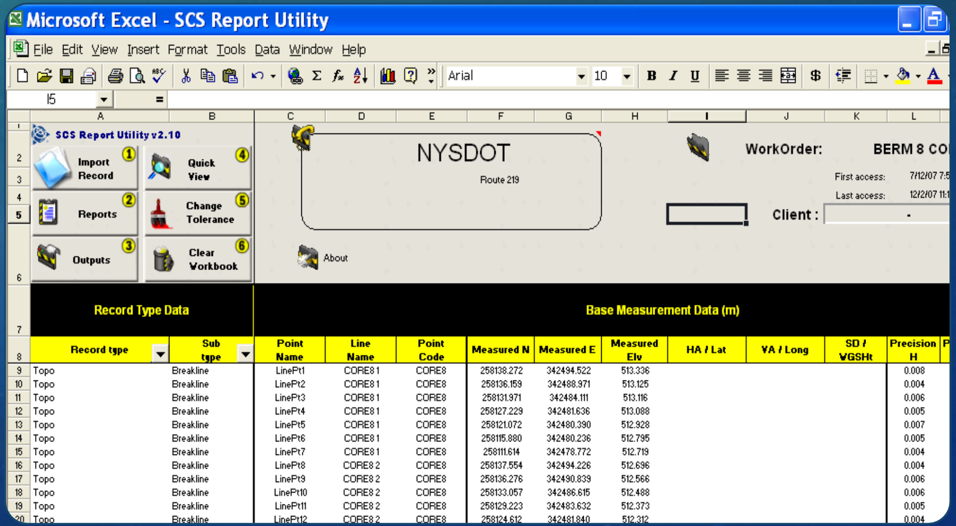
Element
Original mapping control
Survey network diagrams
Coordinate differences
New control
Mapping projection and datum
Method of RTK correction
Site Localization
Surveyor’s seal



GUIDELINES

REAL-TIME VERIFICATION





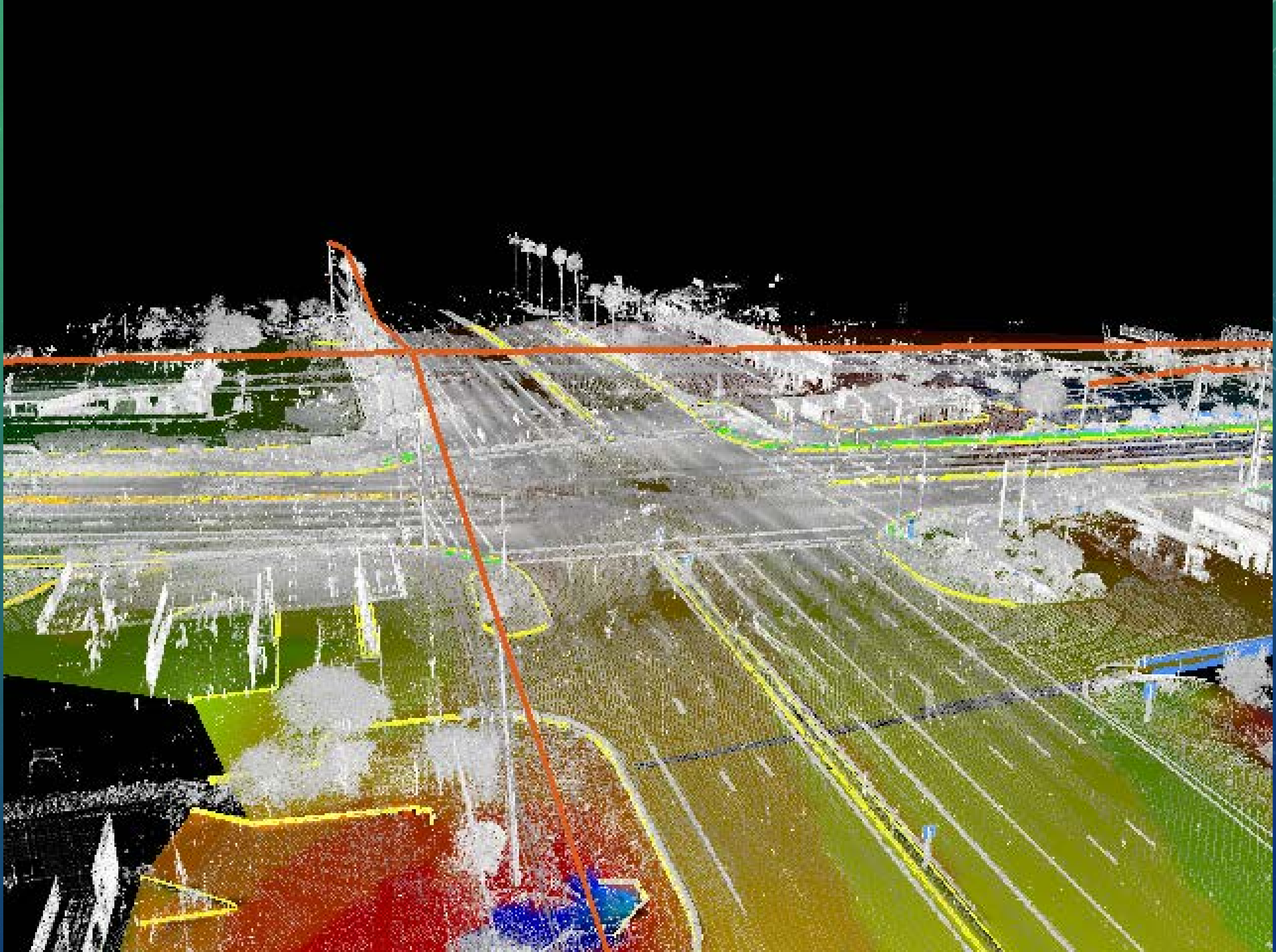
OUTLINES

- Definition of Intelligent Construction Technologies (ICT)
- FHWA ICT Efforts
- Key ICT – Benefits, Challenges and Solutions
- ICT Integration
- ICT Guidance
- **Case Studies**

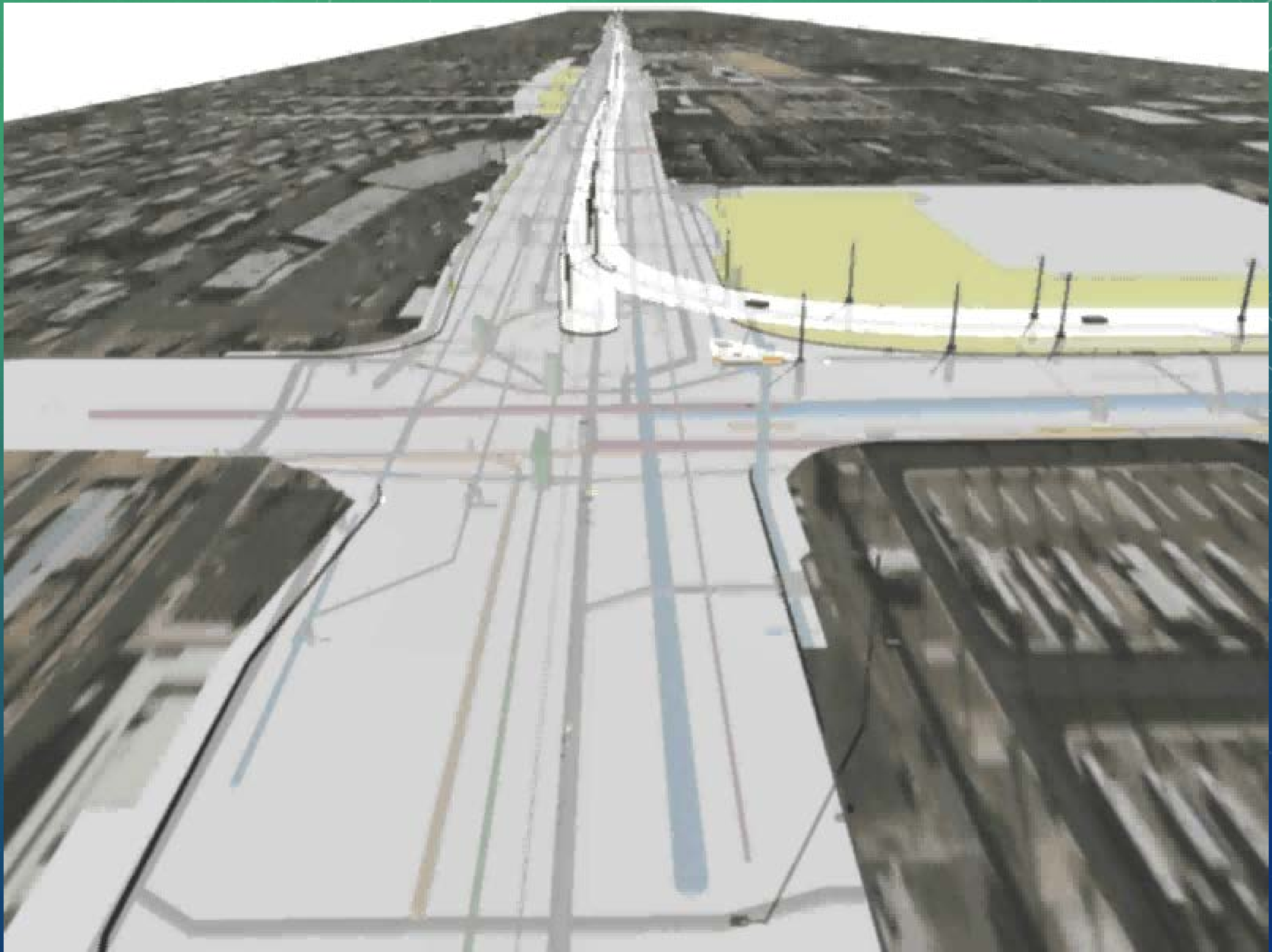
3D SURVEY AND UNDERGROUND CASE STUDIES

- 3D LiDAR
- Underground facility case studies

Courtesy Russell (2012)



ICTG.org



ICTG.org

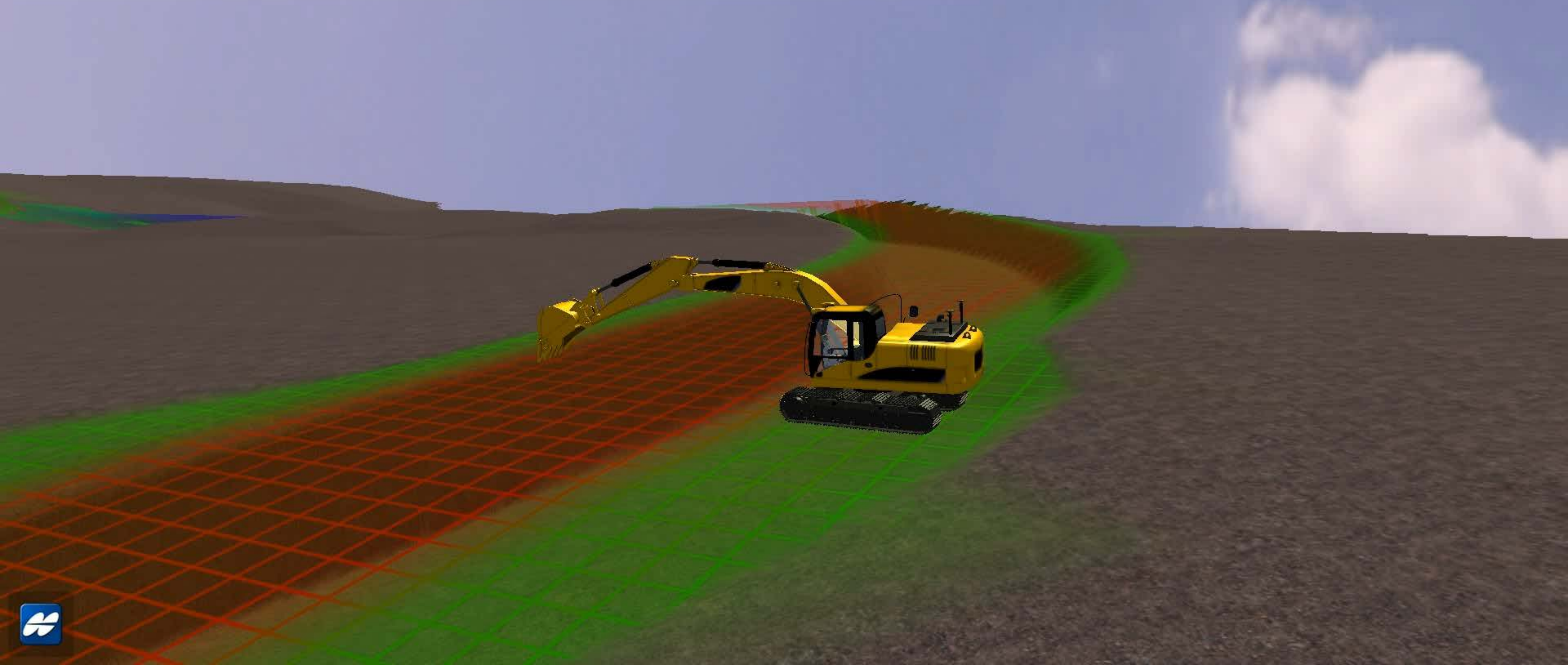
CONSTRUCTION MANAGEMENT CASE STUDIES

- Fleet Management
- AMG for Excavation

Courtesy Jim Preston of TOPCON

Conexpo Road Project

Machine	Type	Status	Operator	Activity	Surface	Alignment	As-built	Position (nez)
TPS_Excavator03	Excavator	Online	PeterW	Cutting grade	TIN_Design1	N/A	Grid_Small	732694.500, 292011.910, 66.630
TPS_BullDozer01	BullDozer	Online	Peter	Dozer Push	TIN_Design1	N/A	Grid_Small	732673.102, 292069.470, 65.597
TPS_MotorGrader02	Motor Grader	Online	TonyT	Fine grading	TIN_Design1	N/A	Grid_Small	732518.607, 292113.950, 50.161



WISDOT CASE STUDIES

- Zoo Interchange
- Watertown Plank Road Interchange

Courtesy Lance Parve of WisDOT

I 80 INTEGRATED CORRIDOR MOBILITY PROJECT

Courtesy Brendan Hafferty of FORUM8

The 80 Integrated Corridor Mobility Project

PATH TO ICT

- Identify More Relevant Technologies
- Quantify the Benefits and ROI
- Identify Challenges and Solutions
- Future Technology Development & Implementation
- Tighter integration
- A Framework for ICT

FURTHER INFORMATION

INTELLIGENTCOMPACTION.COM

IICTG.org

FHWA IC SUPPORT

- Technical Support Service Center (TSSC)
- http://www.IntelligentCompaction.com/Support/
- Phone: +1 (512) 659-1231
- Email: ICSupport@TheTranstecGroup.com
- 5 days a week (Monday - Friday)
- 8:00am to 5:00pm CST

IICTG.ORG

International

Intelligent

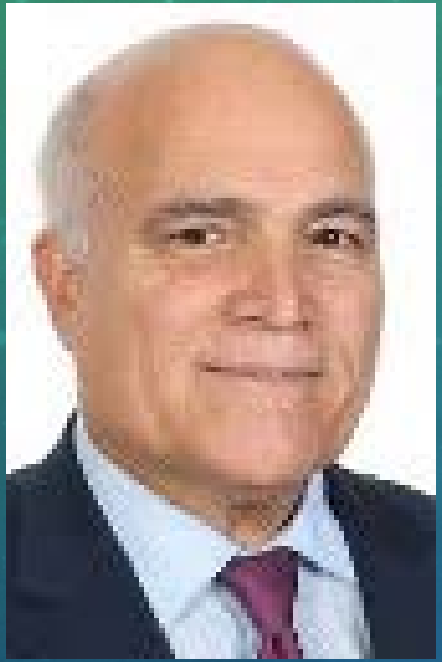
Construction

Technologies

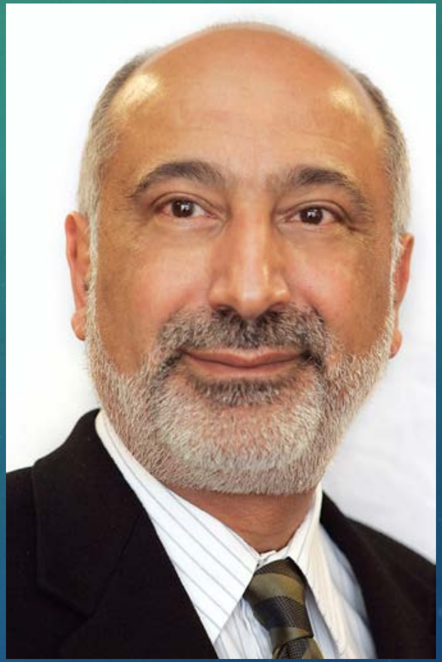
Group

IICTG FOUNDERS

Dr. George K. Chang
Transtec Group, USA
IICTG President



Prof. Antonio Correia
U. of Minho,Portugal
IICTG Vice President



Prof. Soheil Nazarian
UTEP, USA
IICTG Technical Affairs

Prof. Guanghui Xu
SW Jiaotong U., China
IICTG Treasury/Secretary

Thank You!

IntelligentCompaction.Com

IICTG.Org

Dr. George K. Chang, PE

Director of Research, Transtec Group

President, IICTG

GkChang@TheTranstecGroup.com